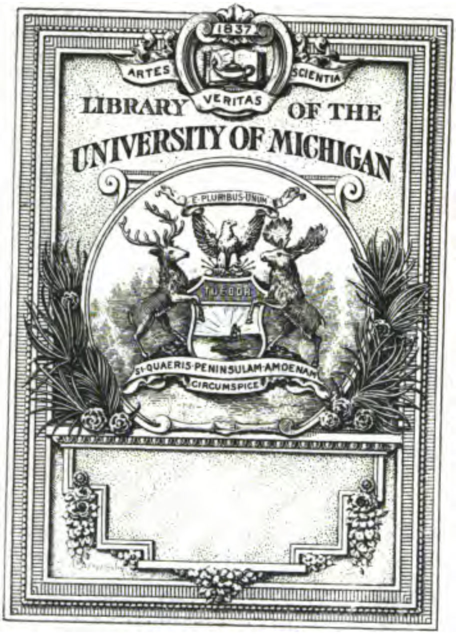

1837
ARTES
VERITAS
SCIENTIA
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
E PLURIBUS UNUM
TUEBOR
SI QUAERIS PENINSULAM AMOENAM
CIRCUMSPICE

THE

DEVELOPMENT THEORY

A

BRIEF STATEMENT FOR GENERAL READERS

BY

JOSEPH Y. oung BERGEN, Jr.

AND

FANNY D. BERGEN

BOSTON
LEE AND SHEPARD, PUBLISHERS
NEW YORK
CHARLES T. DILLINGHAM
1884

THE DEVELOPMENT THEORY.

PREFACE.

IN the preparation of this elementary book on a great subject, the authors have tried to meet what seems to them to be a real need.

To very many thinkers the development theory is the great scientific generalization of the century. Even if it should ever come to appear something less than this, none will dispute the fact that the theory has furnished an incalculable stimulus to the thought of to-day. Yet how few, except special students of the natural or of the physical sciences, really know what is meant by organic evolution! Ask the average graduate of a high school, an academy, or even of one of our minor colleges, to state his conception of the theory. One is ashamed to quote the ready but unmeaning reply, which not seldom would be, "Oh! I know only that Darwin thought we are descended from monkeys."

As well might Newton's theory of gravitation be summed up in the statement that all the heavenly bodies are held in place on the same principle as beads strung on a thread.

The influence of the doctrine of descent is so far-reaching, that every intelligent reader should certainly have so fair a notion of its meaning as to be able, in some measure, personally to test its sufficiency as an explanation of the present condition of the organic world, by applying it to the study of the forms of life about him.

By reason of their very fulness and wealth of illustration, as well as from the necessarily frequent use of technical terms, the classic works of Darwin and the other great founders of the modern view of the origin of species fail to command the attention of the non-scientific reader. The lack of simple and inexpensive illustrated books, which place the outline of the evolution hypothesis clearly before the general reader, has aided in continuing popular ignorance concerning the theory. To assist in supplying this want, as well as to furnish to those who require it an elementary text-book on the subject, is the task which the authors of the present little volume have set for themselves.

Not much in the book is original, except the form in which the facts are presented and some of the examples cited.

To avoid what might have sounded like the editorial *we*, the authors, when speaking in the first person, have throughout used the singular number of the pronoun.

Technical terms have, as far as possible, been avoided, and every thing else has been made secondary to the general purpose of presenting a simple sketch of what Haeckel so well calls "The Natural History of Creation."

CONTENTS.

THE DEVELOPMENT THEORY.

CHAPTER I.

THE QUESTION STATED.

IN the world of living things, there is hardly any thing more wonderful than the variety of kinds, both of animals and of plants. It is this idea of variety, more than any other thought, that impresses one after an hour or a day spent in a museum of natural history; and the impression grows deeper as the student of zoölogy or botany becomes more and more familiar with the extent of the work that lies before him. With this appreciation of the great diversity of the forms of life, there comes, too, another thought.

If there are, of flowering plants alone, probably more than a hundred thousand kinds, and of the flowerless sorts no one can tell how many; if there are, of but one class of animals (the in-

sects), over two hundred thousand known kinds, and probably at least as many more yet to be examined and described; if the population of the earth is as varied as this, — one cannot help asking the question, "How has this multitude of kinds come into being, and what is the use of the earth supporting such a variety of animals and plants?" I may as well begin this account of the development theory by saying, that the latter is the first *scientific* attempt that has ever been made to explain the origin of species. By *species*, naturalists mean much the same thing as is expressed by the commoner word "kinds;" but species is the more exact term, and so, for scientific purposes, the better one to use. A few simple instances will make this clear.

The russet, the baldwin, the pippin, and the greening, are all well-known kinds of apples; yet they are not reckoned as species, but only as varieties of one species, — the apple. Then, again, there are the different kinds or breeds of hens, — the game-fowl, the black Spanish, the Cochin, the Dorking, and so on; all of them classed as varieties of one species, — the domestic fowl.

In these instances the word "kind" means something less than "species;" that is, it does not take in so many sorts of things as the species

does. But sometimes the reverse is true: as, for example, when we speak of the different kinds of cone-bearing evergreen trees, such as pines, firs, red cedars, and so on; for the pines themselves comprise many species, the firs many more, and so with others of the evergreens. In the classification of animals and plants, such kinds, or divisions, as are made up of things very closely alike, and generally *capable of producing others much like themselves*, are called "species." The species, again, are assembled into larger groups, called genera. To make the matter plainer still, let me illustrate it by means of the maple genus. It has five species that are found in the northern United States, east of the Mississippi; of which the best known are the sugar-maple, the red maple, and the water-maple.

The first of these has two varieties, — the common and the black; while the remaining species have no strongly marked varieties: so that the whole genus might be classified in tabular form thus: —

Genus.	Species.	Varieties.
Maple . .	Sugar-Maple	Common.
		Black.
	Red Maple	None.
	Water-Maple, etc.	None.

Now, when we look at the living things of the world about us, we see that the rule seems to be, that life, on the whole, goes on with no great changes from year to year in the species of animals or plants. New individuals come into being, grow mature, become old, and die, only to leave others like themselves; and so the *species* is continued, while the separate animals or plants of which it is composed, one after another disappear. And not only is there usually no great change noticeable during the lifetime of one man; but the pictures, mummies, and other records which have come down to our time from the Egypt of several thousand years ago, prove that the animals and plants of to-day are, in that country at any rate, just about what they then were.[1] It is, from the consideration of this and other similar facts, not unnatural, that, until very lately, men should quite generally have believed that the living forms with which we are familiar were *created*, that is, were suddenly placed upon the earth, in much the same condition in which we now see them.

The father of natural history, the great Swed-

[1] Although this is true of the Egypt of some thousands of years ago, it is by no means true of most countries at a period even so comparatively recent as that just preceding the dawn of written history.

ish naturalist, Linnæus, expressly stated, "There are as many different species as there were different forms created in the beginning by the Infinite Being." And, after quoting this statement, Professor Haeckel, of the University of Jena, Germany (himself one of the greatest of living zoölogists), goes on to state Linnæus's idea of the way in which the animals and plants, after the stranding of the ark, may have lived for a time on Mount Ararat, which in itself, by its situation and height, offers a range of temperature that might suit the needs of a great variety of beings. To this, Professor Haeckel objects, that it would have taken but a very short time for the beasts of prey to destroy all the other animals, or for the latter to eat all the plants. In fact, he argues we cannot believe that the balance of nature could be preserved, if only one or a pair of each species of living things had been created at the outset, or had been rescued in the way just described.[1]

It would seem, indeed, as though there could be no need of even so much as referring to such crude ideas as those of Linnæus just quoted; but there are still many people in the world whose belief is so closely like his, that this sentence

[1] Natural History of Creation, pp. 43-45.

would fairly express their thought. But no one, perhaps, has ever more vividly pictured this process by which all living things are by many supposed to have come into being than has Milton in the well-known lines: —

> "Out of the ground uprose,
> As from his lair, the wild beast where he wons
> In forest wild, in thicket, brake, or den;
> . . . .
> The grassy clods now calved; now half appear'd
> The tawny lion, pawing to get free
> His hinder parts, then springs as broke from bonds,
> And rampant shakes his brinded mane; the ounce,
> The libbard, and the tiger, as the mole
> Rising, the crumbled earth above them threw
> In hillocks."[1]

In much the same way the poet goes on at length to describe the creation of other animals. It may be said that the conception just given is that of a poet, and not of a man of science; but for my present purpose this makes no difference. It is, first of all, to those who have no more scientific conception of the process by which living beings have come to exist on the earth than that of Milton, that the present work is addressed. Linnæus's and Milton's explanation of the origin of species are statements of

[1] Paradise Lost, book vii. l. 456 et seq.

what is known as the *special creation theory.* Whether it is believed in the simple form just described, or whether creation is supposed to have taken place at widely separated points on the earth's surface, and in a manner less closely resembling the process by which the sculptor shapes his clay model, the process is essentially the same. It is not really even an attempt at a scientific explanation of the facts of animal and vegetable existence, but is as evidently a mode of avoiding a real answer to a difficult question as is the explanation which savages give of disease, — that it is caused by the entrance into the body of an evil spirit.

But it has been known, ever since geology became a science, that the beginnings of life on the earth were extremely simple, and of few genera and species. Says Professor Dana, than whom there is no higher American authority, —

> "The earliest representatives of animal life on the earth had no special organs, either of *sense*, of *motion* (excepting minute hairs or hair-like processes), or of *nutrition*, beyond, at the best, a mouth and a stomach. It was life in its simplest or most elemental condition, systemless life; since neither of the four grand divisions of the animal kingdom was distinctly indicated. Such was the beginning."[1]

---

[1] Manual of Geology, p. 161.

In view of this, and of the further fact that it is only after the lapse of many millions of years, and the appearance and disappearance of innumerable legions of species, that we find any thing like the present number of forms of life to have existed on the globe, many scientists have been led to doubt that each species was the result of an act of creation, and have come rather to believe in some form of the *development theory.* According to this latter view (making no attempt to account for the origin of the earliest of all living things on the earth), it is supposed that the present species have been produced by descent, accompanied by changes of form, structure, and habits, from a few simple primitive forms. That is to say, the development theory, in view of all the known facts in regard to extinct and living species, concludes that the latter have been formed, and are now being formed, in a natural rather than in a supernatural manner, by the continued action upon the organisms of forces within and about them. How well this theory stands the great test of all theories, namely, being confronted with facts, it is the object of this little book to show. For twenty years before the appearance of his great work, "The Origin of Species," Mr. Darwin was engaged

in collecting and classifying facts in regard to the occurrence of new varieties and species. Some such facts I will endeavor to state briefly in the following chapter.

CHAPTER II.

CASES OF ORIGINATION OF VARIETIES AND SPECIES.

ONE of the first questions that would naturally occur to any one beginning to think out the problem of the origin of species would be, "Has the time or the manner of beginning of any new species ever been discovered?" How this question is to be answered will depend entirely on what meaning is given to the word "species."

If by it we understand a kind of animal or plant which cannot be shown to vary enough to become the same with any other kind, or to have been changed from any other; which in short is, and from the moment of its origin always has been, perfectly distinct from the nearest similar forms, — then, of course, it would be difficult to answer yes.

Such a definition of species would beg the whole question under discussion; that is, it

would *assume* all that the advocates of the special creation theory wish to *prove*. But if any forms which differ from one another by an amount fairly equal to what, by the general consent of naturalists, usually separates species, may, *whatever their variability or their origin*, be counted as species, then it is easy to answer yes to the question asked at the beginning of this chapter. Yet, in studying cases in which such changes occur as may finally result in the production of new species, it must be remembered that the process of species-making will necessarily often be a slow one. If the human race, the lower animals, and the plants of ancient Egypt, were much the same that they are to-day, it would be foolish to expect frequently to find great changes, in any race of living beings, coming about under our very eyes. At least, no such sudden change can often happen where all the conditions of life have remained as uniform as they have since the dawn of civilization in Egypt.

More than this, since we find, from the evidence of geology, that poplars existed hundreds of thousands of years ago, pines even millions, and that a genus of shell-fish (the *Lingulella*), almost or quite the same with a genus of the present day, has lasted for probably tens of

millions of years, and perhaps much longer,—in view of these things, we are not to expect to find many or great changes in the character of species, with such limited opportunities as we have for observing. Mr. Murphy, in his "Habit and Intelligence," says,—

"If a species were to come suddenly into being in the wild state, as the Ancon sheep did under domestication, how could we ascertain the fact? If the first of a newly born species were found, the fact of its discovery would tell nothing about its origin. Naturalists would register it as a very rare species, having been only once met with; but they would have no means of knowing whether it were the first or last of its race."[1]

Yet, while it is customary to speak of animals and plants as reproducing their own kind, it is a fact within every one's knowledge that this is not literally true in details. Any farmer's boy knows, that in a field planted with yellow or with white corn there will every now and then be a red ear. Plant seeds from Baldwin apples, and you may get half a hundred varieties. While it is well known to market-gardeners and seedsmen, that the seeds from one potato-ball may produce almost as many varieties as there are seeds.

---

[1] Habit and Intelligence, vol. i. p. 344.

It is to prevent this varying, that our fruit-trees are grafted, and partly for this reason, that potatoes are grown from the tuber, or potato itself, rather than from the seed of the potato-ball. Then, again, the double flowers so common in our gardens are all of them, in the botanist's way of looking at things, *monstrous* (that is, unnatural, and incapable often of producing seed); and these flowers are obtained by growing plants in a soil so rich, that vegetation becomes unnaturally rank in it. So the inner parts of the flower (the stamens and pistils) are changed into the leaf-like petals which fill up so much of the mass of the flower in double roses, pæonies, dahlias, and many other species. Such plants as the cabbage, head-lettuce, potato, and all the grains, have been greatly changed by cultivation; some of them so much so, even, that the wild plant from which they were originally obtained would be nearly or quite unrecognizable as the ancestor of the cultivated form.

By this same process of cultivation, the banana has lost its seeds (as have also some oranges); the peach, the celery, and the parsnip have become wholesome instead of poisonous; the crab has developed into the apple; and the wild plum, into the green-gage. In these cases

the offspring is not like the parent; but, through several or many generations, each new crop of seed must have produced a new generation of plants, differing somewhat, and mostly in a particular direction, from the parent. But even more sudden changes are not at all uncommon. Not only does field-corn now and then bear a red ear, but other freaks of this description are of such frequent occurrence, that gardeners are well aware of their existence, and watch for these *sports*, as they are called, in order to obtain new varieties. Among domesticated animals we find even more striking variations than among plants. The dog genus embraces very many wild species, and the cat genus even more. And yet it is an undecided question from what wild species our domestic dog is descended, and not all naturalists are agreed in regard to the ancestor of all the varieties of the domestic cat. In the case of the dog, at any rate, it is not improbable that the many tame varieties are descended from more than one wild species. Of course, the cause of the difficulty in deciding such questions as this arises from the fact, that, under domestication, the dog and the cat have changed so much as no longer closely to resemble their respective wild ancestors. Plenty of other instances of the same kind might be quoted. Again: Mr. Dar-

win has shown, in his "Origin of Species" and his "Animals and Plants under Domestication,"[1] that, while the domestic pigeon is almost certainly descended from one wild species (the wild rock-pigeon), yet the varieties known to pigeon-fanciers differ so much from each other, not only in shape, size, color, and plumage, but even in the number, shape, and size of the bones, and in many other important respects, that a naturalist who met with such varieties in a wild state would certainly class some of them, not only as different species, but even as different genera. In domestic cattle, sheep, horses, and hogs, a similar variability is noticed. It is quite possible for a breeder of cattle, for instance, to take a large herd, and in the course of a few years bring its descendants up to a high standard, either as milkers, or as early fattening beef-cattle. And this he would do simply by going over the herd, and selecting for breeding just those animals which had the qualities desired, allowing no others to breed.

The tendency of plants to sport has already been mentioned, and such a tendency is found to an equally marked degree among animals. The famous case of the Ancon or otter sheep is

---

[1] Animals and Plants under Domestication, vol. i. pp. 137–235.

an example of the kind.[1] The ram from which this breed originated was born in Massachusetts in 1791, and was almost deformed; having very short and crooked legs, and a very long back. The offspring of this sheep inherited the singular form of the parent, and soon became well known and highly prized throughout the neighborhood, from their inability to jump over stone walls and fences. Many large flocks of this breed were reared; and their extension was only stopped by the introduction of the Merino, with its more valuable wool. Another interesting case, cited by Mr. Darwin in the same connection,[2] is that of a lamb born of Merino parents on the Mauchamp farm, in France, in 1828, and remarkable for its long, smooth, straight, and silky wool. The descendants of this sheep became known in France as the Mauchamp Merino, and were widely sought on account of the value of the fleece. In the cases so far mentioned, only cultivated plants and domestic animals have been mentioned. And it is, of course, much easier to find examples of marked variation occurring from the direct or indirect agency of man than to mark the changes which

[1] Darwin's Animals and Plants under Domestication, vol. i. p. 104.

[2] Ibid., vol. i. pp. 104, 105.

take place where he has no part in modifying the conditions under which animals or plants are to live: for, when under his care, they are necessarily the objects of countless experiments on his part; and, in fact, the very process of cultivation or domestication is itself often a long-continued experiment, carried on by generation after generation of men. And it is (as may be inferred from the quotation from Mr. Murphy, in the earlier part of the present chapter) vastly easier to collect observed facts, or gather new ones for ourselves, from those animals and plants which are the objects of constant care and watchfulness, in the domesticated state, than from wild species which are comparatively unnoticed. But we shall find, on examination, variations in a state of nature also, and that the variation, if generally less rapid in each individual case, has been inconceivably greater in amount in the entire wild fauna[1] and flora[2] of the earth than in the comparatively few species which man has taken under his charge. Wild plants, and those in whose culture little care is taken, sport. Every one knows of four-leaved clovers, and I have even seen a specimen of red clover in which

---

[1] The whole series of animals inhabiting any region.

[2] The plants of a region.

one of the three leaflets had grown together by its edges in such a way as to make a little green trumpet of it. I have seen a sensitive fern[1] (a species very common in New England) in which the grape-like fruiting-leaf, or frond, had on one side of the midrib its usual form, but on the other side had grown into broad leaflets, with the fruit borne in little dots on the under side of each (as is the case with most ferns). Here, then, was the plainest kind of evidence of the possibility of the little grape-like cluster at some time, how long ago no one can even guess, having originated by a variation from the usual sort of fern leaf, or frond as it is more properly called.

Such variations as this one would rather interest botanists than those not specially concerned with the study of plants, but there are hosts of freaks displayed in the growth of well-known species. What boy does not know of some hickory (or, as it is called in New England, walnut-tree) which bears nuts of twice the usual size, of a thorn-tree whose fruit is nearly as large as a Siberian crab-apple, and far more palatable, of an oak whose acorns are nearly as eatable as chestnuts, or of a thicket

[1] Onoclea sensibilis.

of wild plums whose fruit is as much superior to the ordinary wild kind as the Delaware is better than a fox-grape? One who is looking for variations in plants can hardly walk through a bit of woods without finding, here a whole tree, there a branch only, that has rougher or smoother bark, or the leaves more or less cut, more or less hairy, or darker or lighter green, than usual. Every treatise upon botany is full of such variations; and the list of *doubtful species* — that is, of plants that may be species, or may only be varieties — is so long, that the number assigned for the species in many of the largest genera of flowering plants would, according to some authorities, be half as large again, or even nearly double the number assigned by Bentham and Hooker in their great work on the genera of plants.[1] Alphonse de Candolle, the eminent French botanist, in summing up the result of his observations on the oak genus, says, that, out of the three hundred species which he has enumerated, *as many as two hundred are doubtful species;* that is, it is impossible to be certain whether they should be counted as species or as varieties.[2]

---

[1] See an article in The Gardener's Chronicle, June 9, 1883.

[2] Darwin's Origin of Species, pp. 40, 41.

Now, this extreme variability, and this linking together of forms which are evidently distinct by others which about equally resemble each of them, is just what we should expect to find if the different species had, as the development theory supposes, descended from some common ancestor.

But this variability is as true of wild animals as it has just been shown to be of wild plants. A few examples only, out of the multitude available, can be quoted here. Among birds, as is well known to students of ornithology, one species is often discriminated from another by the size, in cases where the color and markings of the plumage are found too variable to admit of accurate conclusions being formed from them alone. Yet it has been shown by one of our foremost American ornithologists, Mr. J. A. Allen,[1] that, even in what all agree to call one species, great differences of size occur among full-grown birds, reaching in some cases to from ten to twenty-five per cent of the entire size of the bird; and these variations are accompanied by no less extensive variations in color and markings. Hawks, sparrows, and fly-

[1] The Mammals and Winter Birds of Florida, vol. ii.; No. 3 Bulletin of the Museum of Comparative Zoölogy at Harvard College.

catchers, among our common birds, afford many examples of variable species which cannot be separated by well-defined lines. Among mammals, too, the same state of things prevails.

The lynx, or wildcat genus, is by different authors stated to consist of from one to four species, found in North America and the northern part of the Old World;[1] while certain South-American genera, the Ocelots and Margays for example, are not less difficult to classify.[2] So it is, too, with the little insect-eating shrews, the smallest of mammals; while fishes, in many genera, present an even more perplexing problem to the systematic zoölogist. Of this the white-fish genus and many genera of minnows are examples; while the North-American gar-pikes are variously reckoned as consisting of from three to forty species.[3]

But the most astonishing indefiniteness is found among some of the lowest animals. Dr. Carpenter, one of the foremost zoölogists and microscopists in England, has long ago shown that the foraminifera have only "series of forms," not species.[4] I may explain that the

---

1 The Cat, St. George Mivart, p. 424. 2 Ibid., pp. 408, 409.

3 Jordan's Manual of the Vertebrates of the Northern United States, p. 341.

4 Quoted by Schmidt, Descent and Darwinism, p. 93.

foraminifera are microscopic animals, mere bits of jelly, living in the sea, which produce many forms of beautiful microscopic shells. It is of these shells that common chalk is mainly composed. Even more remarkable is the amount of variation found in one group of sponges, of which Haeckel (the highest living authority in regard to this very group) remarks, —

> "Just in proportion as the systematizer takes the ideas of genus, species, and varieties in a wider or narrower sense, he distinguishes in the little group of chalk-sponges, either only a single genus with three species, or three genera with twenty-one species, or thirty-nine genera with two hundred and eighty-nine species, or even a hundred and thirteen genera with five hundred and ninety-one species. But all these diverse forms are so intimately connected by numerous transitions and intermediate forms, that the common descent of all the chalk-sponges from a single ancestral form, the olynthus, can be proved with certainty."[1]

Again: among the many shell-fish which lived in far greater abundance, and were of larger size and more exquisite forms, in the seas of past ages than can be found in the waters of to-day, the ammonites were pre-eminent; of the same general form and appearance as the lovely

---

[1] Haeckel, Descent of Man, i. p. 117.

pearly nautilus of the present, but with most delicate tracery over the whole surface of the great circular shells, which were often four feet in diameter, as large as a good-sized carriage-wheel — who can imagine the tropical splendor of a sea peopled with creatures such as these?

Certain rocks are found filled with the fossil remains of these great shell-fish; and it has lately been shown that they vary so much, and that so many intermediate varieties are found between forms that were once counted as species, that there can no longer be any doubt that all are descendants of common ancestors. All are related to one another in various degrees, and many of the so-called species are nothing more than varieties of other forms.[1]

In this case the development of species from species has gone on at a rapid rate and on a prodigious scale. But a more instructive, because more complete, story is told by the rocks at Steinheim in Würtemberg, Germany.[2] Here was once a small lake; and in its waters grew countless little shell-fish, many of them water-snails like those of lakes and rivers at the present day. By the appropriation of the dissolved limestone in the waters of the lake, generation

[1] Schmidt, Descent and Darwinism, pp. 97, 98.

[2] Ibid., p. 96.

after generation of these snails built up their shells, only to let them fall to the bottom on the death of the little inhabitant. By this slow process a layer of shell-mud was formed, which has, in the course of the years (some thousands, at any rate) since the deposit was made, hardened into chalk. About forty distinct layers of this chalk, differing from each other slightly in appearance, may be distinguished; and throughout these layers are the perfectly preserved remains of many shells. And now for the wonderful part of the story, for the formation and preservation of a deposit something like the one just described is a common enough thing. The shells of each layer remain much the same throughout its thickness; but toward the limit of each, or before the beginning of the next above, the shells are observed to vary, so as to approach the form of shell *which will be found in the next layer.* And not only are the shells of the lowest layer in the whole series so different from those of the uppermost one that (if the intermediate forms of

FIG. 1.—Variation in Shells of Snails, Steinheim.

shell had not been discovered) they would certainly be called different species; but there are many among the intermediate forms themselves, which, if they had been found separated from the others, would have been counted distinct species. A glance at the figure will make the whole plain.

Here, then, we have the record, preserved in that most trustworthy of all books, the book of nature, of the *growth of a new species by gradual change from a former one;* unless, indeed, we prefer to suppose, that, for an indefinite number of times during the existence of the lake, the snails living at one period were killed off, and another lot created outright to take the place of the former generation. Evidently, to suppose this would be doing much as Voltaire did, when, in order to avoid the necessity for believing that the limestones of south-western Europe were originally formed beneath the waters of the sea, he claimed that the shells of which these limestones are in part composed had been dropped from the hats of pilgrims returning from the Holy Land. Such quibbling, or the assumption that different forms of snail-shell might have been the result of separate acts of creation if they had been found in different places, but are to be regarded as of common descent if found in

the deposit of a single lake, may do for professed wits, but have no flavor of science about them.

But how much more rational is it to believe that the animals and plants of all the geological ages have from time to time been killed off, and new ones made out of earth and air and water, to take their place, than to believe this of the Steinheim snails?

With this brief account of the subject of variation, the present chapter must close, not because there are not examples enough in illustration of the matter to fill many volumes, but because all that it is necessary to do in this place is to show that species may vary till they become changed into other species. Of this fact the case of the Steinheim deposits is in itself a proof; but such instances as are afforded by the oak genus, with its two hundred doubtful species out of three hundred in all, form even more convincing evidence of the irresistible tendency of animals and plants to vary. How sudden and profound such variations may sometimes be is shown by cases like that of certain brine-shrimps, to which I shall refer more fully in the coming chapter. These animals, under changed conditions, were found to vary, not merely from one *species* into another, but from one *genus* into another.

The question as to whether the time or the manner of beginning of any new species has ever been discovered, asked at the beginning of this chapter, cannot be better answered than in the language of Professor Huxley, than whom there is no greater living English zoölogist: —

> "On the evidence of paleontology [the science which treats of the life of previous geological ages], the evolution of many existing forms of animal life from their predecessors is no longer an hypothesis, but an historical fact: it is only the nature of the physiological factors to which that evolution is due that is still open to discussion."[1]

I shall in the next chapter endeavor to explain some of the most important opinions that are held concerning the nature of the "physiological factors" of which Professor Huxley speaks.

---

[1] Article on *Evolution*, in the Encyclopædia Britannica. It may be as well to explain here that different authors use the terms "development theory," "evolution" or "organic evolution," and "theory of descent," to mean about the same thing. "Darwinism" is properly a term of more restricted meaning, as will be seen from Chap. IV.

CHAPTER III.

CAUSES GIVING RISE TO VARIATIONS.

NO one as yet understands, and perhaps no one ever will understand, just what gives rise to the likenesses on the one hand, and the differences on the other hand, that may always be noticed when the parent animal or plant is compared with its offspring. That like produces like is a common enough saying. But the resemblance is never, or almost never, perfect; that is, the animal or plant differs from its parent in size, shape, relative proportion of parts, or in color and markings; while, besides these *structural* differences, there are differences in *function*, manifesting themselves in varied habits, improved or impaired health and strength, or, at any rate, in lengthened or shortened life. But though we must, for the present, dismiss, with no explanation, the great general fact of variation in all offspring of all organisms, yet naturalists have been able to lay down some laws which govern variation; and these it is the

object of the present chapter briefly to state. In this connection, too, it will be necessary to say something of the changes which may be produced in the individual animal or plant during its own lifetime.

In substance it may be asserted, that *any change in the circumstances, i.e., the sum total of the influences affecting any organism, will be likely to work some alteration in that organism or its descendants, or in both.*

Chief among the external influences affecting the existence of any being are the food, soil, climate, supply of light, and the attacks of enemies, either of its own or of other species. To these, in the case of the higher animals, must be added a list of *internal* influences, arising mainly from the habits of life and the disposition of the animal itself.

> "Instances could be given of similar varieties being produced from the same species under external conditions of life as different as can well be conceived, and, on the other hand, of dissimilar varieties being produced under apparently the same external conditions." [1]

Lengthening or shortening the period of life before birth is to be reckoned as another factor, often, among the higher animals, of much im-

[1] Darwin's Origin of Species, p. 107.

portance in producing changes in the character of the offspring. Crossing[1] and hybridizing[2] may account for many varieties.[3]

Of the changes that may be produced by alterations in the medium in which the animal lives, no more striking example could be adduced than one to which allusion has been made in the preceding chapter.

In the summer and autumn of 1871, Schmankiewitsch, a Russian naturalist, noticed that *Artemia arietina* (a sort of brine-shrimp) found in salt-water pools changed its form according to the greater or less saltness of the water. In summer, when the water was most salt, there was a retardation of growth, which was the more marked the higher the temperature, and the salter the water became. When, near the end of summer, the heavy rains set in, and the temperature decreased, the *Artemia* became larger, and lost its red and gray color; so that the November and the July broods differed

---

[1] Breeding between two animals of different species, thus producing a mule, or cross.

[2] Crossing in plants. The term is applied either to animals or plants, but for convenience it is here used only of the latter.

[3] Much may also be allowed for the action of hidden forces at work in or upon the reproductive apparatus, both of animals and of plants; but the action of such forces is at present but little understood.

essentially in size and color. Schmankiewitsch then bred the brine-shrimps artificially. In one vessel he gradually increased the saltness of the water to between four and five times that of ordinary sea-water;[1] in another vessel he reduced the saltness considerably below that

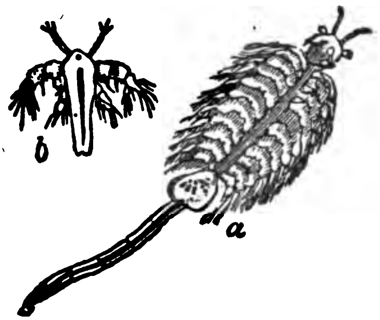


Fig. 2. — Brine-shrimp and Young.

of sea-water;[2] and in both of the series of solutions so prepared he reared several generations. Each new generation lived in a solution of a strength or of a dilution such as the preceding generation could hardly have endured. The new broods of brine-shrimps reared in solutions of varying strength differed greatly from each other, as well as from those in the original pool. Schmankiewitsch also noticed, that in warm

[1] 18° Beaumé. [2] 3° Beaumé.

weather the females, both in the stronger and in the weaker solutions, reproduced without being fertilized. The females hatched from such unfertilized eggs, themselves, in turn, produced a brood of females only. Males only occurred in water of medium strength. Then, in the spring, after the brine had become suddenly freshened by heavy rains, abnormal males were produced.[1] But the two leading forms which Schmankiewitsch obtained have heretofore been known as two different genera, — *Artemia* and *Branchipus;* so that here is a clear case of modifications sufficient to carry an animal from what naturalists rank as one genus into what they call another genus; all taking place by the increase or diminution of salt in the water, more or less aided by variations of temperature.

Yet such changes as this are only immense exaggerations of others, such as are constantly occurring when the conditions of life are changed. The cats of Mombas, on the East African coast, are covered with short, stiff hair, instead of the usual fur; and it is related that a common cat taken to Mombas, after only eight weeks' residence there "underwent a com-

---

[1] This account is in substance taken from an abstract kindly furnished the authors by Professor A. S. Packard, jun.

plete metamorphosis, having parted with its sandy-colored fur." No doubt, in a generation or two the descendants of any cat taken to this locality would become changed into the variety now characteristic of Mombas. In Paraguay the domestic cats are a fourth smaller than the ordinary European variety, and have a coat of close, short, shiny hair. It is only at Ascension, where the native animals probably often interbreed with those brought from abroad, that the breed at all closely resembles that of other parts of the world.[1] It is a well-known fact, requiring no illustration here, that fur-bearing animals in general differ much in the length and quality of the fur, according to locality and climate; so that the skin, which if taken from an individual living in an arctic or semi-arctic climate would be very valuable, may be worth little or nothing when obtained from the same species in warm-temperate latitudes. It is to the influence of climate, at least in part, that the striking variations in the wildcat genus (to which allusion was made in the preceding chapter) should be referred. Food, too, seems to have, in many cases, a marked effect in producing changes in the external characteristics, in

[1] Yet the cats of Paraguay are probably of common descent with those of Europe.

the structure, and in the habits of animals, not only in one generation, but still more decidedly in the course of a series of generations. For example, the domestic cat has intestines a third longer than those of the wildcat; and this fact renders the former animal much more readily able to live, in part or wholly, on vegetable food than the latter would be.[1] Again: there is noticeable, says Mr. Darwin, a tendency, among some civilized races of men, toward losing the usefulness of the wisdom-teeth. In some instances these never appear; while in others they are small, and soon decay. On the other hand, these teeth, in the skulls of certain prehistoric men, were (as shown by skulls and jaws that have been discovered in various parts of Europe) much larger and stronger than in civilized races of the present day. In the celebrated jaw found at La Naulette, Belgium, the front grinder or molar is the smallest, and the wisdom-tooth the largest, of all; while the whole set of teeth is extremely strong, and fully developed. But we know that these prehistoric men lived in the rudest way, partly on the flesh of huge wild animals, which must often have been

[1] Animals and Plants, etc., ii. pp. 292, 293. The wildcat is not the ancestor of the domestic breed, but the comparison is at any rate instructive.

eaten raw, or nearly so. Their vegetable food must have consisted of nuts, acorns, berries, wild grains, and perhaps roots; and it is easy to see that such a diet must have demanded long canines or eye-teeth, fully-developed grinders or molar teeth, and a power of jaw for which the civilized man of the present has no occasion. Just these peculiarities distinguished the skulls of some of the earliest known prehistoric races; and it seems but fair to assume that the man of our time, the lineal descendant of these savages, is losing in strength of teeth, just because he is so entirely a cooking animal as he is.

Among the lower animals, similar causes have produced even more striking effects. In the common hog, for instance, the effect of plenty of food, and a release from the dependence which the wild boar must place on ploughing up the ground for food, has been greatly to shorten the head, at the same time diminishing the strength of its bones and of the muscles of the neck, as may readily be gathered from the figure in the margin. So far has the shortening process gone, that, while the proportion of the length of the head to that of the body is as one to six in some of the common breeds of hogs (and much more than this in the wild boar), in the most improved breeds, the proportion is only one to eleven.

Fig. 3.—Head of Wild Boar, and of "Golden Days," a pig of the Yorkshire Large Breed.

Mr. B. D. Walsh, one of the best known American entomologists, has shown that many kinds of insects vary much from the influence of the different kinds of plants on which they feed; and his investigations point strongly to the conclusion that even *species* are originated anew among insects by changes in their food.[1]

Color is one of the most variable of the characteristics of animals. As an example of the effect of food in producing color-changes, it may be stated that bullfinches and some other birds become black when they are fed on hemp-seed; while the common green parrot is, in South America, made to blossom out in red and yellow by being put upon a diet of fish-fat.

In such a case as that of the snails at Steinheim, so often cited, it is impossible to say whether it was a change of temperature, of food, of clearness in the water, or of all these, with still others besides, that produced the modifications of the snails, which are so manifest from layer to layer of the chalk-deposit in which they are found. But it is at any rate a very suggestive fact, that, whenever the character of the chalk-layers appears to have changed, the snails are found to have altered with it. No less

---

[1] Darwin's Origin of Species, pp. 38, 39.

remarkable is the fact, that young oysters transplanted from the north-west of Europe into the Mediterranean, at once begin to grow into the peculiar form, with diverging rays on the shells, characteristic of the Mediterranean oysters.

Allusion has been made to the éffect of light; but it is not generally easy to trace this directly, except in the case of plants, where it is in part responsible for the extraordinary development of vegetation in tropical regions. Indirectly, however, its importance may be gathered from the appearance of such animals and plants as are partially or entirely withdrawn from its influence. Cave-fishes and cave-insects, for example, are, as is well known, frequently quite blind; and this blindness is generally attributed to the effects of disuse of the eyes, caused by the absence of light. Hardly less noticeable than the blindness of these animals is their transparent, blanched appearance, which is undoubtedly due to the partial or complete darkness in which they have lived. Cases are not wanting, again, of animals in which, from the effect of partial disuse, certain organs are found in a very imperfect condition. It is to this cause that most naturalists would attribute the defective eyes of the mole; and Mr. Darwin cites the case of a

burrowing South-American rodent,[1] the tuco-tuco, in which he often found the eyes inflamed and upon the point of becoming useless, probably from the animal getting dirt into them while underground. But in this interesting case the result, after many generations, would probably be, that the animal (under the operation of a law which will be stated in the succeeding chapter) would at length lose its eyesight altogether.

It may be in some measure due to the absence of light, that horses kept for several years underground, in the Belgian coal-mines, become covered with a soft coat of fur, like that of the mole.

Turning, now, to the influence of causes connected with the reproductive system on the origination of varieties, it will be necessary here only to mention the influence of the length of the period of gestation on the character of the offspring.

It has been argued by some naturalists, that since all the higher animals pass, in the course of their embryonic life, through a long series of stages, — from the form of an egg at the outset to that of the perfect animal at last, — any pro-

---

[1] A gnawing animal, like the squirrel or the rat.

longation or shortening of the time of gestation (or in the case of birds, reptiles, fishes, etc., of the time passed within the egg) would produce marked differences in the young. The subject, however, is too difficult, and too few facts are known, to support any definite conclusions, or to admit of any thing further being said here in regard to the matter.

In connection with this subject a word must be said in regard to a singular fact; namely, that some animals may breed either in a fully developed or in an imperfect and widely different condition. The Mexican axolotl is a striking instance of the kind. It is a tadpole-like creature of considerable size, which lives in the water, breathes by gills, and is reproduced from eggs.

FIG. 4.—Axolotl.

In its native country, Mexico, this animal is not known to change its form, but hatches from the egg into a minute object much like a young tadpole, and gradually grows to the form and

proportions shown in the figure above. Other species much like the axolotl occur in high regions, as in Wyoming, seven thousand feet above sea-level.

FIG. 5. — Amblystoma.

Now, in 1867, the astonishing fact was observed at the Jardin des Plantes, in Paris, that some of these animals cast their skins after crawling out of the water, and began a new existence in the shape of a common salamander (*Amblystoma*).

How different looking the salamander is from the axolotl the figures above given well illustrate. And the real difference between the animals is no less than the apparent difference: it may fairly be compared to that between a water-snail

(which breathes by means of gills, and would soon die in the air), and a land-snail, which has a simple organ answering the purpose of a lung; so that the animal, if placed in water, would drown. But this astonishing change from axolotl to salamander is accomplished in from fourteen to sixteen days, and, it seems, may always be brought about in healthy specimens by placing them in shallow water, and gradually diminishing the supply.[1] The salamanders produced in the way just described lay eggs, which hatch into tadpole-like larvæ that soon grow into salamanders.

Now, since the axolotl-descended salamanders are of precisely the same species with other salamanders found in the western United States, it seems certain that these wild individuals are descended from axolotls; and it has been suggested that a dry season, or a succession of such seasons, first caused this change to take place. If so, we have here a most striking instance of changes of climate producing, not merely another species, but another *genus*.

Turning, now, to the subject of crossing, a few facts may be given in regard to its occurrence, and its influence on the production of species.

---

[1] Wilson, Chapters on Evolution, pp. 242–244.

It is hardly possible to account for the extraordinary differences in form, size, disposition, and habits of the domestic dog, without supposing that the present races are descended, not from one, but from several, wild species, which have crossed and recrossed till the many known races have resulted. In fact, no wild species can be pointed out as at all closely resembling, even a majority of the domestic kinds. Add to this the fact that the latter may be crossed with wild dogs of different species, with wolves, with jackals, with foxes even,[1] and in all cases but the last (if not in that), the offspring of the cross breed freely with either parent species, and sometimes with each other. It is true, domestication often seems to be essential to the removal of a sterility frequently noticed when wild animals are crossed; but there are abundant instances of the fertility of the product of such crosses, either with one of the parent species, or with each other.[2] The domestic cat also crosses freely with wild species, probably with not less than nine different ones;[3] and the result of the crossing is to produce mongrels which generally breed freely.

[1] Darwin, Animals and Plants, etc., i. pp. 21–34.
[2] Haeckel, Natural History of Creation, vol. i. pp. 147, 148.
[3] Darwin, Animals and Plants, etc., i. pp. 46, 47.

How readily plants hybridize, one *race*[1] with another, is well known to all who have had much to do either with farming or with gardening. Pure seed cannot be raised from sweet-corn planted near field-corn, nor from melons grown near squashes or pumpkins. Broom-corn and sorghum, too, are notoriously likely to hybridize when grown in each other's vicinity. The hybridizing is in all cases brought about by the fertilizing-dust (pollen) from one plant falling on the tip of the seed-producing organ (pistil) of the other plant, and there sending out little tubes which penetrate the whole length of the pistil, and cause the immature seeds (ovules) contained within its base to grow and ripen. The transference of the pollen from one plant to another is accomplished by the wind, or by insects travelling from flower to flower. The same process is often carried on artificially, with the intention of producing new varieties, as in the production of the well-known Rogers Hybrid grapes. In the cases just cited, the hybridizing takes place between varieties of the same species; but there are plenty of instances of its occurrence between different species, resulting in the production of perfectly fertile seed.[2] So

---

[1] By race an extremely well-marked variety is meant.

[2] Darwin, Animals and Plants, etc., ii. pp. 107-112.

common is hybridism in certain wild genera of plants, notably among the oaks and the asters, that it is impossible to decide, in regard to certain forms, whether we should call them species, varieties, or hybrids. In view, then, of the known facts, — of which the ones just cited form but an insignificant fraction, — it seems at least to be altogether probable that many species of animals, and still more species of plants, have originated by crossing and by hybridization.

So far, in this chapter, only the operation of more or less perfectly understood causes of variation has been considered. It is easy enough to see how even so remarkable a change as that of the axolotl into the salamander may be brought about by its removal from the water and the consequent loss of its gills. But the instances in which changes are produced by causes which are imperfectly or not at all understood, are far more numerous and striking than the better-understood kind. The very real though almost indescribable alteration which Europeans undergo, after a generation or two, on being transplanted to this continent, forms an excellent example of the all-pervading effect which may result from causes too minute to be entirely separated from one another, and too

various for all of them to be detected. In this instance, climate has undoubtedly much to do with the changes observed; yet many other influences must co-operate with it. But, of all the perplexing problems that are presented to the student of variations in animals and plants, there are none more perplexing than the exceptional or monstrous births, and the "sports," that so frequently occur. Several examples of this kind have already been given in Chap. II., but something more may be said in this place in regard to such occurrences. It seems to be a general rule, that, the more a species has varied, the more it will vary; so that, when a gardener wishes to get a variation in a certain direction, he will do well to select plants that vary much from the usual form, *even if they are changing in just the opposite direction to that desired*, since they will be likely sooner or later to show variations in the direction that is wanted.[1] But just why the variation *begins* is unknown; though it is a well-ascertained fact, that abundance of food has much to do with putting species into a condition to vary.

A striking instance of the fact that these extraordinary births, for some unknown reason,

---

[1] Darwin, Animals and Plants, etc., ii. pp. 249, 250.

tend often to repeat themselves in a certain manner, is afforded by the case of the black-shouldered peacock. This kind differs greatly from the common peacock; being considerably smaller, and in both sexes differently colored from the latter. So decided are the points of contrast, that Mr. Sclater, a very high authority, insists that the black-shouldered bird is properly to be ranked as a distinct species. It has made its appearance, that is, been found originating from eggs of the common kind, not less than seven times in England, and has sometimes multiplied so fast, as after a little while to become the only kind in the flock of its owners.[1] This happens, too, in spite of the fact that it is so much smaller and weaker than the latter as to be always beaten in the frequent fights of the males. Had the black-shouldered kind originated in the wild state, it would (as already explained in the passage quoted from Mr. Murphy) have been impossible to decide when or how it came into existence; and who would have hesitated to class it as a new species? Is it not likely that at least a part of the cases similar to that which Mr. Wallace reports, of a humming-bird found in only one spot, the

---

[1] Darwin, Animals and Plants, etc., i. pp. 305–307.

crater of an extinct volcano in South America,[1] may have for their explanation some such recent origin as that of the black-shouldered peacock?

Such apparent accidents as the birth of six-fingered and six-toed children, of others with scales all over the body, of albinos (individuals without the proper supply of coloring-matter in the eyes, skin, and hair), come under the head of sudden and unexplained changes, due, possibly, to some kind of pre-natal influence. Melanism, or the presence of too much coloring-matter, the exact opposite of albinism, is, like it, a condition occurring both among men and the lower animals. Most of these singular variations may at times become hereditary, as may also most of the "sports" in plants; so that it would be as possible to secure a race of six-fingered men as it was to stock farm after farm with the Ancon and the Mauchamp sheep. All are familiar with the wide propagation of albinos in the domesticated state, in the case of white mice and white rabbits.

In this connection it is important to notice the fact of *correlated variation;* that is, variation of several parts or organs together, whenever,

---

[1] Island Life, p. 16.

from any cause, a change is produced in one of them.

It is not remarkable that the hair, fur, or wool of animals, their horns, and their teeth should vary together; for the zoölogist has learned (from their material and their early mode of growth) to regard all of these structures as intimately related to each other.

Accordingly we find in the often-quoted Mauchamp merinos, for example, the horns, like the wool, smooth and comparatively straight. Hairless dogs generally have imperfect teeth (sometimes only one on either side of the jaw). Not infrequently the male animal (as in the hog, some apes, and the horse) has more fully developed teeth, especially canine or eye teeth, and a more hairy body, or hair more fully developed on some part of the body, than is found in the females. And from similar correlation the curious hairy woman, Julia Pastrana, who had a full beard and a hairy forehead, had also two rows of teeth, one inside the other.[1] White cats with blue eyes are generally deaf; but this, it may be, is only a special illustration of the general fact that albinos are usually endowed with less acute senses than most of their species.

[1] Darwin, Animals and Plants, etc., ii. p. 321.

From the same cause, perhaps, in Virginia white pigs cannot be raised in certain localities, because they are poisoned by eating the paint-root.[1] It has not been definitely ascertained whether this is due to the greater sensitiveness of the white pigs to the poisonous root, or to the fact that their sense of smell is not keen enough to enable them to detect it, while that of the black ones is keen enough for this. In the vegetable kingdom, the same sort of correlation exists, and to such an extent, that (to give one instance out of many) experienced growers of apples can even tell from the shape of the leaves of a *new seedling*, before it has ever borne fruit, pretty nearly what the character of the fruit will be.[2] By this correlation of variations, a change set up in one part is likely to be accompanied by many other changes.

In the foregoing portion of this chapter, only here and there an instance of specific change, out of the great store of accumulated evidence on the subject, has been cited; and, in reckoning up the amount of such change that has taken place during the entire life-history of the earth, it must be remembered that the present, according to geologists, is an age of unusual

---

[1] Origin of Species, p. 9.

[2] Darwin, Animals and Plants, etc., ii. p. 324.

stability on the earth. Animal and vegetable life, in the present geological age, is thought to be in a state of much less rapid change than characterized it during earlier times; and it is not unlikely that this is due to the present slow rate and small amount of change in the conditions of life.

Let us place ourselves, then, in a position to realize as fully as possible the great effect upon transmutation of species that must have been produced by the world-wide and profound alterations in the earth's surface which are known to have taken place through past ages. Let us remember how inconceivably long those ages were in comparison with any periods of time during which scientific observations have been made by man, and we shall, I think, feel, that, in this brief period, naturalists have found change enough going on to justify the inference that all species, from the beginning, may well owe their existence to similar causes with those just mentioned, vastly greater in amount, and acting through stupendous periods of time. How variations of species, once having been produced by such causes as those just described, have been preserved and intensified will be explained in the next chapter.

CHAPTER IV.

CAUSES WHICH HAVE PRESERVED ADVANTAGEOUS VARIATIONS.

"A STRUGGLE for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction during some period of its life, and during some season or occasional year, otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product. . . . Linnæus has calculated, that if an annual plant produced only two seeds — and there is no plant so unproductive as this — and their seedlings next year produced two, and so on, then in twenty years there would be a million plants. The elephant is reckoned the slowest breeder of all known animals, and I have taken some pains to estimate its probable minimum rate of natural increase. It will be safest to assume that it begins breeding when thirty years old, and goes on breeding till ninety years old, bringing forth six young in the interval, and surviving till one hundred years old : if this be so, after a period of from seven hundred forty to seven hundred fifty years, there would be nearly nineteen million elephants alive, descended from the first pair."[1]

[1] Origin of Species, pp. 50, 51.

In introducing the subject of the present chapter, I quote these few sentences literally from Mr. Darwin; because he has done so much more than any other investigator to call the attention of the scientific world to these facts, which, up to the time of his researches and publications on the subject, had, for the most part, passed unobserved, or at any rate unregarded. And so it has become almost impossible, even in the simplest statement of facts concerning the rate of increase of living beings in its relation to the origin of species, to avoid giving the substance, if not even the exact language, of Mr. Darwin.

In the two estimates just quoted, a plant and an animal with an exceptionally slow rate of increase were purposely chosen. As an example of the opposite kind, the codfish may be taken. At one spawning it produces from four to nine million eggs, each of which, if allowed to hatch, would in the course of a few years grow into a fish of from five to twenty pounds' weight. It is easy enough to see, that if all the eggs hatched, and all the young cod grew up, their natural rate of increase would very soon pack the waters of the ocean brimful of fish. More rapid still is the rate of multiplication of the little microscopic plants (*Bacteria*), which are now generally rec-

ognized as the chief cause of decay or putrefaction. So rapidly do they increase, that for the offspring of a single individual (itself invisible to the naked eye) to fill the waters of the ocean would take at most but about five days.[1]

A striking instance of the rapidity with which, under favorable circumstances, animals have actually spread, is given by Mr. Darwin in his account of the rabbits on the Island of Porto Santo, near Madeira.[2] These were introduced by a female rabbit with young being left on the island in 1418 or 1419 by the crew of a passing ship; and they soon became so abundant as to force the settlers on the island to abandon it. Their rapid increase may be attributed to the fact that no birds of prey, or other animals capable of destroying the rabbits, existed on the island; and the climate, as well as the supply of food, must have been especially well adapted to their wants.

It is interesting to notice that these rabbits have changed so much (becoming nearly three inches shorter, and almost one-half less in weight, than wild English rabbits, besides undergoing considerable changes in color), that they would not now, if found in the wild state

[1] Cohn, quoted by Burrill, The Bacteria, p. 9.
[2] Animals and Plants, etc., vol. i. pp. 117-120.

with their history unknown, be ranked as of the same species with the English rabbit. And the naturalist would be still less likely to consider them as identical with the latter species (which is the same as the Spanish ancestor of the Porto Santo breed) from the fact that they will not cross with the wild English rabbit.

It is well known how soon new breeds of domestic cattle, sheep, or hogs, if found desirable, become prevalent over wide regions; so that it was said in England, that the introduction of short-horned cattle operated almost like a pestilence in the destruction of the earlier and less improved breeds. Of course, the comparison to a pestilence means only this, — that the owners of the older sorts killed them off, or disposed of them to the butcher, at such a rate as to thin them out as fast as the cattle-plague could have done it.

The same holds good in regard to the introduction of desirable new agricultural plants, as, for instance, in the case of the Early Rose potato. Seeds, tubers, bulbs, or cuttings of new varieties, will usually, in the course of four or five years from the time of their introduction, be so common as no longer to command a price much above that of older varieties. Similar to the spread of the Porto Santo rab-

bits has been that of the Norway rat over Eastern Europe and most of North America, and that of the English sparrow in the United States. Such weeds as the "jimson" (Jamestown) weed, the English charlock, the Canada thistle, and many other plants introduced into this country, have spread at an astonishing rate; and an insignificant water-plant (the Anacharis), on being introduced from this country into Great Britain, has there so increased as almost to block up rivers and canals, though here no trouble of the kind is noticed. Animals and plants, then, are kept from spreading so as to overrun the entire surface of the country in which they live, not by any lack of power to multiply so as to fill the space, but by the attacks of enemies of every description, as well as by heat, cold, moisture, drought, or famine; the last check being often produced by excessive crowding, either by members of their own or of other species. It has been remarked by those familiar with the woods of Northern Maine and the adjacent region, that deer are alternately plentiful and scarce. This seems to be almost certainly due to the fact, that, in the abundant years, wolves are attracted into the country from the extensive woods of Canada, and gradually increase in number till they destroy, or

drive out, very many of the deer. After this, upon their supply of food becoming scanty, the wolves, during successive years, either die out, or remove to more desirable hunting-grounds, thus leaving the few deer which have been spared to increase, comparatively unchecked until they again become abundant. But upon this the wolves are once more attracted back, and so the series of changes is repeated. In this instance, then, the number of deer is evidently, in great measure, dependent on the fewness of the wolves; or the scarcity of deer, upon the abundance of the wolves. In something the same way the grasshopper (locust) invasions in the South-western States have generally been checked by the rapid increase of insect parasites, which prey on the locusts to such an extent as to put a stop to their increase. So, again, in some portions of the wheat-raising region of the South-West, the chinch-bug has become so destructive to all kinds of grain, that the farmers are obliged to give up planting grain, and to raise crops (such as flax) which are not attacked by the bug.

The result seems to be, that, with the removal of its favorite food, the insect becomes less and less abundant till grain-raising once more becomes profitable. Whole regions of

country otherwise well adapted to sustain a given kind of animal may be rendered unfit to do so by the presence of some seemingly insignificant enemy. In portions of South Africa, according to Dr. Livingstone, the attacks of the tsetse fly make the country uninhabitable for horses, oxen, or dogs; though the bite of the fly is not specially injurious to other animals or to man.

Paraguay, too, says Mr. Darwin, is unable to support wild horses, cattle, or dogs, from the presence of a fly, which is very abundant, and which deposits its eggs on the new-born young of the animals just mentioned. On the other hand, the existence of any of these flies (and, in fact, of most insects) depends very largely on the number of insect-eating birds in the country. The number of the latter, again, depends upon their greater or less liability to the attacks of birds of prey, of egg-eating birds, of snakes, and of many animals of the cat tribe. And these enemies of the insect-eating birds are largely kept in check by human agency.

Starvation has been named as one of the enemies with which living beings have to deal, and it is indeed one of the most deadly. All are familiar enough with cases of its operation in the animal world, killing off, as it does, innu-

merable individuals of all ranks, from man to the lowest. But among plants its action is not less widely fatal; and it is to this cause, in great part, that the "running-out" of old pastures, for instance, is due. The same cause, together with lack of sunlight, produces the barrenness of undershrubs, and even of smaller plants, which characterizes dense forests, such as those formed by the heavy growth of willows, sycamores, elms, and hackberries, that skirt the banks of so many Western rivers. In pine and other evergreen woods, the effect is still further heightened by the carpet of "needles," or "spills," which covers the ground so closely as effectually to prevent the growth of any but a few species of plants. To appreciate the kind and number of seeds of plants of all sorts, either lying dormant in the soil of pine-forests, or annually distributed upon it, one has only to observe the number of fire-weeds, raspberry-bushes, and many other species, springing up quickly after the pine-woods have been cut down, and the ground burnt over.

And this first growth is, in turn, displaced by a colony of young oaks,[1] interspersed with birches and alders; so that, in the course of

[1] In some parts of New England sugar-maples and chestnuts also.

twenty-five years at most, the area at first covered with pine-forest will be found occupied by a growth of deciduous[1] trees. These, on being cut away, will, in turn, be followed by pines and other evergreens.[2]

I have mentioned severe cold among the causes which destroy animals and plants, and there can be no doubt of its frequent and extensive agency in the work of destruction. Mr. Darwin has calculated, that from this cause, in the severe winter of 1854–55, four-fifths of the birds on his own grounds perished; and he goes on to say, "And this is a tremendous destruction, when we remember that ten per cent is an extraordinarily severe mortality from epidemics with man."[3]

No doubt many wild plants, too, are killed by extreme winters, just as we know is true of peach-trees, osage-oranges, and winter-wheat, among cultivated plants.

Enough has now been said, perhaps, to exemplify the cause and nature of the struggle for existence, as well as some of the living enemies and the hostile physical forces with which all

---

1 Shedding the leaves in the autumn.

2 This statement is made from personal observations in Eastern New England nearly twenty years ago.

3 Origin of Species, p. 54.

organisms are obliged to contend. To the action of the various forces opposed to life, in weeding out all those individuals which are least qualified to live, Mr. Darwin has given the well-known name of *natural selection.*

Herbert Spencer, the distinguished English philosopher, calls the process "*the survival of the fittest;*" and either name well expresses the result of that action of natural forces on the living world which has been briefly summed up in the preceding part of this chapter. A few added words may help to make clear just what is this result.

In case many of the animals or plants of a region are destroyed, it is evident, that, in the great majority of cases (whatever the cause of the destruction), *the killing-off will not be indiscriminate, but will first and mainly comprise those individuals which are least able to avoid the attack.* For example, it has been found inexpedient in Belgium to raise white carrier-pigeons, because they are so much more likely than the darker sorts to be pounced upon by hawks. But, curiously enough, on the west coast of Ireland the sea-eagles pick out black hens from the flock; so that "the villagers, as much as possible, avoid rearing birds of that color."[1]

[1] Darwin, Animals and Plants, etc., ii. p. 215.

And the same difference in liability to destruction from various causes is found among plants. Trees bearing purple plums are more exposed to the attacks of the black-knot than are those which bear green or yellow plums. Yellow-fruited peach-trees are the ones which suffer most from the fungus producing the *yellows* on the leaves. And near Malaga, Spain, at the beginning of the attacks of the vine-disease, the green grapes were the most severely affected; "and red and black grapes, even when interwoven with the sick plants, suffered not at all."[1]

And again: after some striking instances showing the very great difference which certain individuals of some species of bean show, when compared with others of the same species, in their power of resisting frost, Mr. Darwin says, —

> "It was impossible to behold these three plants, with their blackened, withered, and dead brethren all around, and not see at a glance that they differed widely in constitutional power of resisting frost."[2]

The dwarfish or misshapen sapling will be elbowed out of existence by its sturdier neigh-

---

[1] Darwin, Animals and Plants, etc., ii. pp. 214, 215.

[2] Ibid., ii. p. 300.

bor; the sick buffalo is the one that the wolves will drag down after the herd has passed; and of the drove of wild horses it is only the slowest and weakest that can be run down and caught. It has already been shown that variation, whether among animals or plants, is not the exception, but the rule; that not merely do slight variations occur, but sometimes very sudden and great ones, as in the instance of the axolotl and that of the brine-shrimps.

It is not pretended that natural selection is capable of *giving rise to variations*, but only that it acts in an extraordinarily powerful and certain way (from the immense scale on which it operates), in giving additional chances for life and reproduction to any *desirable* varieties that may be produced. Says Dr. Gray, in his "Darwiniana," —

> "Natural selection is not the wind which propels the vessel, but the rudder, which by friction — now on this side, and now on that — shapes the course. The rudder acts while the vessel is in motion, effects nothing when it is at rest. Variation answers to the wind."

By the action of such causes as have been enumerated in the preceding chapter, countless variations must continually be produced, and many of these variations must be in favorable

directions. Then, of course, those favored varieties which thus gain better means of offence and of defence; which can obtain food more readily, or live on less food; which reproduce more abundantly, or take better care of their young, — will be the fittest to survive, and will survive. One of two results will then follow: either the new species will displace some individuals of the parent-species, and so flourish side by side with the old form, or (more commonly) the new species will at length entirely take the place of the old one. Only in very rare instances (that of the salamander, for example) can the new form live under such different conditions from its parent-species as not in any way to affect the numbers of the latter. And so, with much the same result as that which the farmer obtains by selecting his seed-corn, the gardener by thinning out his beds, or the cattle-raiser by selling off all his roughest calves for veal, Nature is at work, on an inconceivably great scale, thinning out the least perfect individuals of every species.[1]

---

[1] Mr. Darwin has been much criticised for personifying nature, and for speaking as though natural selection were a conscious matter. This he does not mean. No one who advocates his theory means thereby to imply the necessity of consciousness; and it is as allowable to speak of natural selection as to use the expression, "the howling of the wind."

Now, just as business competition is most active in the largest cities, and as business methods are there brought to the highest pitch of perfection, so we find (and apparently from a similar cause) that in the great continents the animals are better fitted for the struggle for existence than they are in such a small continent as Australia, or than they are in any island far out at sea. Such wingless and defenceless birds as have been found in great numbers on some islands could have existed but a few days at most in the presence of such enemies as they would necessarily have encountered if placed on any continent. Birds like these, then, were not well adapted for varied conditions of life, and could never have existed over wide areas; but they form only an extreme instance of the general fact that the animals of islands or of small continents have not been so severely thinned out by all sorts of destructive causes as have those of the great land-masses. Perhaps the force of this argument will be more evident if it is illustrated by the well-known fact that improved breeds of cattle nearly always originate on farms where large herds are kept and bred; so that there is chance for a wide range of selection on the part of the stock-raiser. And the same is true of improved plants: they

originate usually in the great gardens of the florist or of the market-gardener, who cultivates, it may be, many acres of one species. It is easy to understand, with this explanation in view, how sometimes the present fauna or flora of an island should resemble that of large portions of the earth during some one of the earlier geological ages. This is actually the case with the flora of Madeira [1] and (as will be seen in a succeeding chapter) with the fauna of Madagascar. What, then, should we expect to find occurring when the animals and plants of an oceanic island like St. Helena are suddenly brought into competition with those of a continent? In this case of St. Helena, the question has been experimentally answered; and the result of the introduction of European animals and plants, whether by accident or design, has been almost to supplant the native species. So, too, the animals and plants of Europe drive out the native productions of New Zealand, and, in some degree, those of Australia; for, although Australia is properly to be ranked as a continent, the long period that has elapsed since it has been connected with any mainland has left its fauna and flora in a very backward or anti-

---

[1] Darwin, Origin of Species, p. 83.

quated condition. In both Australia and New Zealand the English rabbit has multiplied in such a way as seriously to threaten the success of the farmers. The native carnivorous animals seem unable to keep down the intruders. Of the seriousness of the situation in New South Wales the "Illustrated Sydney News" says, —

"The keeping of rabbits of any kind is now prohibited by law, there being a penalty of a hundred pounds for every offence proved. This may seem severe; but it is stated that the rabbit-pest can be traced in a large measure to a few rodents which were thoughtlessly let loose. It is marvellous how rapidly their numbers become multiplied in the pastoral districts, in several of which they have completely eaten out the sheep. In reference to the ravages of these unwelcome animals, Mr. Maxwell of Cobar says, 'Once rabbits get on a run, it is a constant outlay. In a small paddock of forty acres I have seen three men constantly killing four and five dozen per day for months together, and still they kept coming. That was twelve years ago. They tried killing for several years. Before rabbits came, we used to have seventy to eighty per cent of lambs, and ran three sheep to four acres. In less than three years we could not rear a lamb; and it took four acres to keep one sheep alive; and all our cattle died.

"'Then we fenced with paling, and kept them out of the run, and kept killing; that is, trapping, shooting, hunting with dogs and ferrets, and poisoning. The brutes kept coming most of the time into the little paddock, as it was the sweetest feed. There are still rabbits

on the place, and men have to be kept to keep them down.' At first Victoria was the principal sufferer; but somehow or other the rabbits have crossed the Murray, spreading devastation and panic throughout the south-western portions of the colony, and ruining the prospects of numbers of hardy settlers. How far the Rabbit Nuisance Act will aid in abating the evil remains to be seen; but, if it fails, the situation will be one of the gravest character."

Of the remedies suggested for the difficulty, the ones that seem most likely to do away with the evil are the importation of polecats from Europe, or of mongooses (little carnivorous animals, often called ichneumons) from Asia, to kill off the rabbits. Of New Zealand, "Dr. Hooker states that the cow-grass has taken possession of the roadsides; dock and water-cress choke the rivers; the sow-thistle is spread all over the country, growing luxuriantly up to six thousand feet; white clover in the mountain districts displaces the native grasses; and the native (Maori) saying is, 'As the white man's rat has driven away the native rat, as the European fly drives away our own, and the clover kills our fern, so will the Maories disappear before the white man himself.'"[1] And what

[1] Professor E. L. Youmans, article "Darwinism," in Johnson's Cyclopædia.

is so forcibly here stated in regard to New Zealand is more or less true of every island far from any mainland.

On the other hand, what would be the result of exposing a great continent like Europe-Asia (the largest land-mass in the world) to invasions by animals or plants from islands or small continents? Here, again, experiment has answered the question; and it is found, that, as Darwin says, "hardly a single inhabitant of the southern hemisphere has become wild in any part of Europe."[1]

I have spoken in a preceding chapter of the great differences in the varieties of domestic dogs and cats, and of the differences between these and wild species. Now, when dogs or cats are allowed to run wild, they do not become identical with any existing wild species; and this same fact is noticed in regard to most domesticated animals when turned loose to shift for themselves. From this it seems most reasonable to conclude that our domestic animals are substantially new species, produced by the long-continued action of human selection

[1] It must be remembered that the southern hemisphere consists of relatively small and narrow portions of land, and that these have at times been quite cut off from the northern hemisphere.

and of changed conditions of life on the descendants of the original wild stock. The same failure to return to a state resembling any known wild species is noticed in the case of some cultivated plants which have run wild. But if we find that changes so great as to create new species have occurred among domesticated animals and cultivated plants as the result of man's selection, acting only through some thousands of years; and if these new species are at times so permanent as to seem indestructible by natural agencies, — what may not the selective action of Nature through unknown ages have accomplished? May not Nature, acting in the manner already described for perhaps more than fifty millions of years,[1] have been able to produce from a few forms of life, or even from one form, all the long series of living and extinct species? But it is not alone to the agency of natural selection, powerful as that certainly has been in perpetuating new forms, and taking advantage of every beneficial variation, that the whole work of establishing and protecting new species is to be ascribed.

Among the higher animals, a process to which Mr. Darwin has given the name of "sexual se-

---

[1] Dana's Manual of Geology, p. 591.

lection" seems also to have taken part in the encouragement and perpetuation of variations. The combats of male animals are familiar to every one. It is the rule, rather than the exception, for the male to fight with other males for the possession of the female; and this is true of animals as wide apart in size and rank as the buffalo (bison) of our Western prairies, and the stag-beetle or "pinch-bug." Even if one of the combatants is not killed outright in these duels, the weaker animal, in being defeated, loses the choice of feeding-ground, and, in some cases, the necessary protection of the herd to which he properly belongs; and of course he loses, for the time being at any rate, the opportunity of breeding with any female of the species. It is not even necessary that there should be a combat, or that a contest of strength even, should arise between two of the males, in order to give an opportunity for preference to be shown by the female. Throughout the animal kingdom, almost without exception, it is the male who courts and pursues the female; so that he is in every instance compelled to use all means to secure her favor. And so far as the most competent observers are able to judge of the matter from the behavior of animals, and particularly of male song-birds, at the breeding

season, it is allowable to infer that the females of the lower animals are by no means indifferent to what might almost be called the *personal* attractions of individuals of the opposite sex.

But, if this be granted, it is clear that we must admit that the color or the form, that the power or quality of the voice, as well as courage and physical strength, may be important in influencing the choice by female animals of the sires of the next generation. Here, again, as with natural selection, there would be a strong tendency to retain certain qualities, and encourage their highest development; for any desirable modification would give its possessor so much of an advantage (in the manner just described), that this modification would be very likely to be perpetuated.

So far, in the treatment of the subject of development, the two theories of the origin of species have been stated; then the amount of variation in all living things has been outlined, its causes have been discussed, as well as the causes which tend to perpetuate new species once formed.

In the coming chapter will be presented some curious and interesting indirect proofs that in both the animal and the vegetable kingdom there has been development of some sort.

CHAPTER V.

MIMICRY AND ALLIED PHENOMENA.—INSECT FERTILIZATION.

IT has probably been known, ever since men first began to observe the appearance and the habits of animals, that the latter often take their color and markings, sometimes even their shape, from the objects among which they live. The white winter-dress of the arctic hare and the ptarmigan are only striking instances of a world-wide series of such imitations among animals. Any one who has at low tide ever floated along in a boat over the green and brown gardens of dulse and other seaweeds among which the common flounder lives, and on which he feeds, must have noticed how difficult it is to distinguish his smooth, flat, indistinctly marked upper side (*not* his back) from the sea-bottom which he hugs so closely.[1]

[1] This paragraph was written long before the authors had seen Grant Allen's charming account of the matter.

In many rivers of the Mississippi basin, too, there is a curious fish, the "hog-sucker," whose back is so mottled with shades of brown, that even the expectant fisherman, who knows how palatable this sucker is, will often fail to drop in his triple-pointed "jig-hook;" for the fish lying quietly on the creek-bed is very nearly indistinguishable from the stones about him. How hard it is, too, to see the quail (bob-white) or the prairie-hen as it squats under the very muzzle of the gun.

The green dress of the katydid, the gray of moths which alight on the bark of trees, the green color of plant-lice, the transparency of jelly-fish and many defenceless marine animals, the colors of the chrysalis[1] of certain caterpillars found at the Cape of Good Hope, varying with the material to which the chrysalis is attached — all these further illustrate the kind of imitation just mentioned. Other animals, however, afford still more striking because completer resemblances. Our common stick-bug, or devil's walking-stick, is far outdone by tropical insects of similar form; while the leaf-like katydid is much less perfect in its imitation than a species of phyllium, a kind of leaf-like

[1] The nearly or quite immovable condition which caterpillars assume before changing to butterflies.

insect found in Java, of which the distinguished English naturalist, Alfred Russell Wallace, relates that residents on the island often keep one of these insects on a branch of the guava-tree as a puzzle for strangers, who are told that the

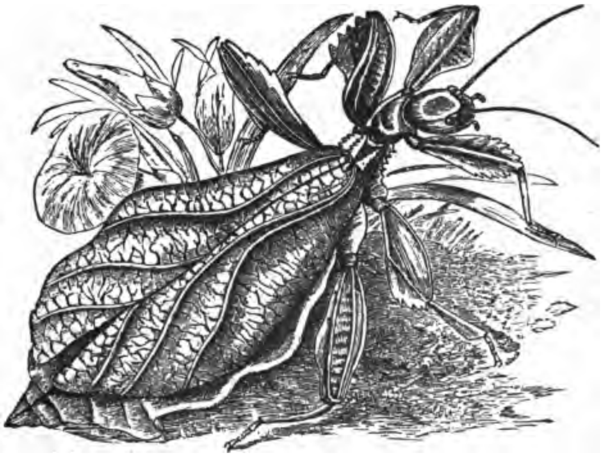


FIG. 6.—Leaf-Insect.

insect is on the tree, but are unable to find it among the leaves. More striking still, if possible, is the resemblance of the leaf-butterflies, as they sit with folded wings, to a leaf of the tree or shrub on which they are in the habit of alighting; so that, even in the figure here

given, it is not easy at first glance to distinguish the insect which is perched upon the twig.

How successful these resemblances sometimes may be in protecting the insect from its enemies, is well shown by an observation made by Mr. Belt, a capital English naturalist. On one occasion he saw a multitude of insect-eating ants run about and over the body of a large, leaf-like locust. As the latter remained perfectly still, the ants did not recognize it as being an insect at all, and so left it unharmed.[1] A curious insect, a phasma, which Mr. Wallace found in Borneo,[2] was so covered with olive-green growths, that the native who showed it to him was sure that the insect really was covered with live moss. It may be added that this insect greatly needs some such protection as that afforded by this curious resemblance; since it is very sluggish in its habits, and is greatly relished by insect-eating birds. In the well-known cases of chameleons and tree-frogs, which change their color apparently at will, it is possible that two ends are subserved, — the protection of the animal from its enemies, and the facilitation of its unobserved approach to the

---

[1] Wallace's Tropical Nature, p. 93. [2] Ibid., pp. 92, 93.

FIG. 7. — Leaf-Butterfly, in flight and in repose.

flies and other insects upon which it feeds. Somewhat similar to these cases is that of a mantis, or praying-insect of Java, which is pink, and closely resembles a certain flower, an orchis, found in the same region. The advantage of this resemblance to the mantis will appear plain when it is stated that it lives upon butterflies, and that the whole group of plants to which the orchis belongs attracts butterflies and moths.[1]

Quite as curious as the cases of what have been called *protective resemblances*, such as those of the white hare, fishes, insects, and other animals, or as the sort of *decoy resemblances*, as they may be named, like that of the mantis, are the instances of what are known as *warning-colors*. Many South-American butterflies, belonging to two divisions, the *Heliconidæ* and the *Danaidæ*, are remarkable for the brilliancy of their coloring and for their slowness of flight. From these characteristics they form, as may be imagined, very conspicuous objects; and their numbers are not less remarkable than is their showiness. The secret of their numbers is plain, however, to the naturalist who captures one of these resplendent fellows; for all the species have a

---

[1] Wallace's Tropical Nature, p. 173.

most disgusting odor, which clings for a long time to any object that has touched one of them. It has been ascertained, that, probably for this reason, the insect-eating birds and lizards of the region where these butterflies are found refuse to have any thing to do with them. It is therefore an advantage to these uneatable species to be so differently colored from others, and so slow of flight as they are, since it thus becomes easy for the birds and lizards to recognize and avoid them. Another instance of the same kind occurs in the case of some of the Central-American tree-frogs, whose gorgeous coloring for a good while perplexed Mr. Belt. Some of these frogs had a brilliant red body and blue legs, while others were entirely of a bright blue color. But the mystery was solved, when the naturalist one day tossed one of these gaudy little frogs to a young and inexperienced duck, which at first picked it up, but instantly dropped it, apparently as much disgusted with the taste as it would have been pleased with that of an ordinary frog.[1] Still another instance, perhaps, of the same sort of thing, is to be found, as Mr. Wallace reminds us,[2] in the brilliant coloration of the uneatable sea-slugs and sea-anemones.

---

[1] Tropical Nature, pp. 175, 176. [2] Ibid., p. 180.

But the whole subject of warning-colors needs to be further studied; and it is likely, that, in very many instances, some useful object may be subserved by bright coloring. Not improbably the brilliancy of such insects as the beetle, that feeds so abundantly on the leaves of dog-bane, and the great rhinoceros-horned dung-beetle, so common in many parts of the country, serves to advertise these insects as uneatable.

Similar in purpose, possibly, to the warning-colors just described, are such striking appendages as the rattle of the rattlesnake, or the expanded neck of the cobra di capello,[1] which may be explained, not as kindly warnings to the passer-by, that he may avoid the snake, and escape its fangs, but rather as a notice given by the snake on its own account, to show that it is a dangerous customer, and is better left alone. The flattened neck and head of the puff-adder, which is perfectly harmless, but looks, when it raises itself to strike, not a little like one of the poisonous snakes, is probably another case of mimicry for the sake of protection. So, too, there are tropical bugs which closely resemble wasps; while among our own insects many flies are found which look so much like bees or

[1] A very poisonous snake, found in India, which flattens out its neck and head like a hood, on being disturbed.

wasps, that the young collector is slow to venture to put his hand on them. Again: the *Danaidæ* and *Heliconidæ*, already mentioned, are mimicked by other South-American butterflies, of genera which are eatable by birds. In all such cases it is observed that the kinds which mimic are far less abundant than the species which they resemble; and this must be so, if the mimickers are to pass unnoticed among the multitude of the really uneatable kinds. The imitation is so wonderfully close, that even experienced collectors can hardly distinguish the imitation heliconias and danaids from the true ones. If the naturalist can be so deceived, does it not seem certain that this similarity must also deceive the enemies of these butterflies, and that individuals of the imitating species must often escape by this means, when they would otherwise be captured and eaten? The first observations on these interesting cases of mimicry among butterflies are due to Mr. H. W. Bates,[1] while Mr. Wallace has added greatly to our knowledge of the subject. Among plants, observed cases of mimicry are much more rare than with animals; and yet it has for years been one of the unexplained facts of botany, that certain plants

[1] A full account of these facts will be found in his Naturalist on the River Amazon.

of the orchis group produce flowers which closely resemble butterflies and other insects. It is evident, that, since the principal causes which operate in the destruction of plants are other than the attacks of animals, protective resemblances and warning-colors would be of comparatively little use to a plant; and accordingly the botanist finds few or no cases which may certainly be classed under either one of these heads.

There are, however, some phenomena manifested by plants, which have an important bearing on the development theory, and which may best be stated in this connection. Darwin[1] and Wallace[2] have called the attention of botanists to the fact, that those fruits which are eaten by birds or other animals large enough to swallow the seeds whole are, in general, of some other color than green, and that the seeds or stones in them are usually so hard or tough, that, when swallowed whole, they cannot be digested, but pass nearly unchanged through the stomach or intestines of the animal. In some instances the softening process undergone in the digestive cavities of the animal seems even to hasten the sprouting of the seed. Now, from the two

---

[1] Origin of Species, p. 161.

[2] Tropical Nature, pp. 224, 225.

facts just stated, the coloration of fruits and the indigestibility of seeds,[1] the most natural conclusion is, that the fruit is colored as a result of the action of natural selection; that is, colored fruit would be more readily found among the green leaves of the plant by birds or other animals, and so be eaten when uncolored fruits would be left. That this is not mere guess-work has been shown by Mr. Darwin's observations on the consumption by birds of pale and of bright-red berries of the English holly. He found that a much larger proportion of the bright-colored berries than of the pale ones were eaten.[2] In the same way the indigestibility of seeds may be attributed to the action of natural selection, tending to perpetuate those variations in any seed which would make it more able to resist digestion, and so to grow after having been swallowed. If it be asked, "What advantage can it be to a plant to have its seeds swallowed?" I answer, that much would be gained for the plant by transference of its seeds to another spot from that on which they were produced; for certainly one of the greatest difficulties with which plants have to contend is

[1] The words "seed" and "fruit" are used in this chapter in the popular, not the botanical sense.

[2] Animals and Plants under Domestication, ii. p. 216.

overcrowding, and the worst kind of crowding is that which comes from individuals of the same species. It would be easy enough for many hazel-bushes to grow in the shade of an oak, for greenbriers and blackberry-bushes to crowd themselves in among the hazels, and for a large variety of herbaceous plants to grow closer to the ground, among the bushes. But two oaks could not have grown to full size in the place now occupied by the one, nor could the bushes, with the oak removed, have grown enough larger to make up for its absence, or the oak have done much more without the bushes than with them.

So the economical growth of plants demands that provision be made for distributing seeds as widely as possible; and accordingly we find a variety of other methods at work, besides this rather complicated process of having the seeds swallowed. Burs are carried by unwilling animals often to great distances; winged fruits and seeds are carried by the wind; the thick husk of the cocoanut floats it over tropical seas, so that the feathered crown of the cocoa-palm is the first and often the only tree-like form encountered on coral-islands many hundred of miles from the mainland.

In the Mississippi basin there are several grasses, some of them very troublesome weeds,

whose soft, plumy heads break off from the parent stem as soon as the seeds are ripe, and travel overland, rolling along before the wind, for vast distances. Not less curious than the arrangements for general distribution are some of the modes by which seeds are locally distributed; that is, thrown or carried to a short distance from the plant that bore them. The balsam, or touch-me-not, throws its seeds several feet by the bursting of the capsule in which they are contained. In the wild crane's-bill the little pouches in which the seeds ripen are attached to elastic slips, which are at first united about a central column; but, as the seeds ripen, these slips break loose, and fly out into a little coil, while the seed is thrown to a considerable distance.

Stranger still, the spores[1] of such microscopic organisms as the red snow-plant (*Protococcus*) and many others are provided with little hair-like oars, called cilia, with which they swim off through the water. The instances just quoted, though only a few out of the multitudes that might be brought forward, will perhaps serve to give some idea of the generality and the importance of the provisions for scattering the seeds of plants.

---

[1] Little particles answering nearly the purpose of seeds: in flowerless plants they take the place of seeds.

It has just been stated that plants do not (as far as is known) exhibit the phenomena of warning-colors or of protective resemblances; but it is true that the coloration of flowers, their perfume, and the presence of nectar[1] in them, are always of great service to the plant.

Sir John Lubbock, an English banker of the highest reputation as a naturalist, in his fascinating lectures, relates, among many careful observations, positive experimental proof that bees and wasps are attracted by bright colors, and that they prefer the same odors that men do.[2] Every housewife knows that the smell of fresh meat or fish quickly attracts the large blue-bottle flies; while such odors as that of boiling fruit or of hot vinegar, not only attract flies, but bees, wasps, and hornets as well. I have seen the door and window screens literally swarming with these insects, about a kitchen where peaches were being scalded in spiced vinegar.

It is now proved beyond doubt that the color and odor of flowers enable them to utilize the services of insects while guiding them to the store of nectar inside. Flowers that have

---

[1] Commonly (but wrongly) called honey: the latter is a manufactured product, due to the bee.

[2] Scientific Lectures, p. 31 (and in many other passages).

no nectar are, as a rule, neither bright-colored nor sweet-scented; while those that have it are usually attractive in one or both of these ways. Now, it has been found that such attractive flowers are dependent on insects to carry for them the fertilizing dust, or pollen, from one flower to another; and that, unless the pollen is so carried, few or no perfect seeds will be ripened by the plant. In any flowering-plant the production of seed depends on the transference of pollen from the male parts, or stamens, of the flower, to the female parts, or pistils; but it was until recently thought by most botanists, that any fresh pollen of the same species of plant would answer the purpose. This, however, has been disproved by the investigations of Darwin and others; and the fact, as stated in a preceding paragraph, that attractive flowers depend on insect-fertilization is now undisputed. On the other hand, such inconspicuous flowers as those of the grasses, rushes, and sedges, as well as of many forest-trees and other plants, either depend on the transference of pollen by the wind, or are capable of self-fertilization; that is, of using the pollen in the flower in which it is produced. It needs little calculation to show that the plant would generally be benefited in the struggle for

existence by being adapted for insect-fertilization rather than for fertilization by the wind; since the former method economizes the strength of the plant by requiring less pollen to be produced, and also makes the result far more certain, thus giving a better guaranty for the preservation of the species. Out of the multitude of examples of the marvellous arrangements for securing insect-fertilization, described in such books as Lubbock's "Scientific Lectures," and Darwin's "Fertilization of the Orchids," a single case must suffice for the purposes of the present chapter. The flower of salvia, as represented in Fig. 8, is two-lipped in form. Its

FIG. 8.—Diagram of Flower of Salvia, and of its Stamens.

anthers, *a*, *a*, mature before the pistil, *p*, shown in *A*. A bee visiting any newly opened flower

of the salvia would become dusted over the back with pollen from the ripened stamens. These have their anther-cells pivoted to the filaments (*B*, *f*, *f*) in such a way that the insect, on entering the flower, must tilt both anthers into the position shown at *C*. In this position it will be noticed (Fig. 9, *A*) that they lie close-

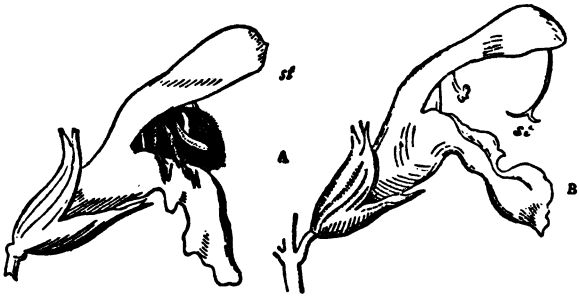


FIG. 9.—Salvia Flowers of Different Ages, one visited by a Bee.

pressed against the bee's back. Now, when she flies to an older flower of the same species, the bee no longer finds the stamens in position, as in the former flower: they are shrivelled up out of the way, and their place is taken by the stigma (*B*, *st*). The position of the stigma is such that it will just brush the insect's back, and so rub off from it a little of the pollen brought from the former flower. How carefully

the pollen is economized! And yet this is by no means as wonderful an arrangement of parts as is found in many orchids. But insects, while foraging for themselves, may be made to work for plants in ways quite different from those already explained. Mr. Wallace states[1] that certain acacias with large hollow thorns, by means of the sweet pulp stored in these thorns keep a standing army of savage ants, which first feed on the pulp, and afterwards live in the cavity from which it was taken, still finding food on the tree, in the shape of honey-glands on the leaf-stalks, and of small fruit-like bodies, both of which seem to be much relished by the insect-guests of the tree. Mr. Belt (from whom Mr. Wallace obtains these facts) concludes, from his study of the case, that the ant-army is useful to the tree by protecting it from the leaf-cutting ants, which destroy great numbers of such trees as are not guarded against their ravages.

In all the cases cited in the present chapter, — whether of warning-colors or protective resemblances among animals, or of contrivances among plants to secure the aid of insects in fertilization, or for other purposes, — the process

[1] Tropical Nature, p. 89.

of natural selection may be understood to have turned to account any great or small variations in a desirable direction, and preserved them, till the present wonderful series of adaptations is the result. That this has been the method by which the whole result has been reached seems all the more likely from the fact, that, in nearly all the classes of phenomena described in this chapter, there are arrangements to be met with, *of all degrees of perfection*, for securing the desirable result.

If every protective coloration or resemblance were as perfect as that of the arctic hare, or of the leaf-insect of Java, or if every warning-color were as brilliant as that of the Central American tree-frogs, or if all the provisions made for the distribution of seeds were as effective as we find in the case of some burs, or if every case of insect-fertilization secured the necessary result as perfectly as is done in the salvia, it might well be asked, "Where are the successive steps by which this perfect adaptation of means to ends must (according to the development theory) have been reached?" But it is, in fact, far oftener the case, that the adaptation is very imperfect, than that it is as faultless as in the examples just referred to. In the katydid and the common green grasshopper the

same kind of modifications as those which may be supposed to have given rise to the leaf-insect have proceeded but a little way. The snow-bird is only partially white, and therefore not protected to any such degree as the ptarmigan. It would seem that the banded body of the hornet, and the steel-blue, metallic-looking body of the mud-wasp, must be useful to them mainly or altogether as warning-colors, which would protect them from the attacks of other animals, particularly of birds, many of which are known not to eat stinging insects. But, from the rapid flight of the insects in question, the protection cannot be nearly as complete for them as it is for the slow-flying heliconias among butterflies, or the tree-frogs, which are in the habit of remaining for hours nearly motionless.

Of the seeds which are known to be in some way especially adapted for dispersal, only a few are so perfectly provided for as the cockle-bur or the thistle; but there are far more, which, like the beggar's-ticks or the maple, are provided only with the means for securing a short journey. And out of about a hundred thousand known species of flowering plants, there are comparatively few which show adaptations for insect-fertilization at all equal to that of the salvia. In the great majority of cases, even

among those plants which depend on attracting insects, and utilizing their visits, the pollen is jostled off by the insect in one flower, much of it blows away, and only a small portion lodges on his back or head, while of that which does so lodge only an insignificant part is caught upon the stigma of the flower to which he goes.

It is, of course, possible to advance the supposition that all the cases of mimicry and its related phenomena among animals, and of special arrangements for insect-fertilization, and so on, among plants, were *created*, in all their complexity, just as we now find them. But how would the advocate of such a theory explain the wastefulness and imperfection of the transference of pollen in all but a few exceptional cases, or reconcile such short-comings in the work of an all-wise and all-powerful Creator? Why, if the vegetable and the animal kingdom were created as we now see them, might not every plant have been made capable (as many actually are) of self-fertilization? Or why not have protected the acacias by leaving the leaf-cutting ants uncreated? for the latter serve no discoverable useful purpose, but spend their lives in stripping plants of their leaves, and preparing from the bits of leaf artificial mushroom-beds or rather mould-gardens, on the product of which they live.

It is the privilege of the student of natural science to ask such questions as these, and to draw the material for his answers from the heaped-up observations of naturalists everywhere.

And if, from the point of view of the development theory, the phenomena of the living world offer to the observer an exquisite picture of the interaction of natural forces on the living organism in just those cases, which, from the special creation stand-point, can appear only as bunglingly complex contrivances to secure a simple result, who can doubt which view of the matter is the true one?

CHAPTER VI.

THE TESTIMONY OF EMBRYOLOGY.

THE present chapter will try to explain the bearing of the development of individual animals or plants, from the moment when life begins, on the general theory of organic evolution.

But it will first be necessary for the reader who is not already somewhat familiar with the outlines of classification of animals and plants, to consult a brief account[1] of the leading types or forms of life met with in the animal and in the vegetable kingdom; since, without this elementary knowledge, the facts of this and the following chapter cannot be appreciated, nor their bearing on the development theory understood.

At the bottom of the lowest sub-kingdom of animals, the protozoa, is the class monera, ac-

---

[1] See Appendix A.

cording to Haeckel. Seen through the microscope, one of these simplest of animals appears at first as a mere roundish or irregular-shaped speck of animated jelly (protoplasm) of about the same size[1] as one of the colorless cells (white blood-corpuscles) which are found in human blood, that is, about the three thousandth of an inch in diameter. Soon, it may be, this speck will be seen to put forth from any part of itself little blunt extensions, — false-feet,[2] we call them, — and to creep about very slowly by reaching forward with some of these false-feet, then drawing itself forward to where their extremities were placed, and so on. A particle of some vegetable substance comes into contact with one of these feet; and at once the living jelly flows out, around, and over the foreign material, till the latter is quite enclosed, and here it stays till whatever was nourishing has been absorbed from it, when the indigestible portion is squeezed out through any part of the body of the animal, and so rejected. The protamœba (for this is the animal's name) has no eyes, ears, nose, mouth, lungs, heart, stomach, nor any digestive organs, so far as the best microscope can see; its chemical composition is

---

[1] The dimensions, however, are very variable.

[2] Pseudopodia.

much the same as that of the white of an egg; and it differs from an extremely small drop of this substance mainly in being alive. That it is alive is evident, not only from the fact of its moving and feeding in the way already described, but also from the fact of its reproducing. One of the largest among a number of these minute organisms may often be noticed to become drawn in or smaller about the mid-

FIG 10.—Multiplication of a Moneron by Self-Division.

dle: it assumes a sort of hour-glass shape, and soon separates into two parts, thus producing two animals from one by *self-division* as it is called.

Ascending a step above the monera, we find animals of the genus amœba, with a little more variety of parts than the Protamœba possessed, since each contains within its jelly-like mass a particle of firmer consistency than the rest,

called the nucleus; and this nucleus often shows within itself the presence of a still smaller particle, the nucleolus. Somewhere within the body of the amœba there is also a little sac, which alternately grows larger, and almost disappears, expanding and contracting like a microscopic heart. When the amœba is reproduced (as it always is) by self-division, the only essential difference between the process and that already described in the case of the Protamœba is, that the operation now begins by the pinching-in of the kernel or nucleus, followed by a division of the whole animal as before. In some species, too, it may be noticed that the whole bit of protoplasmic jelly which composes the animal becomes covered with a tougher coating, and the body becomes more nearly spherical in shape, before the process of self-division begins. In one orange-colored moner described by Professor Haeckel,[1] the life-history is in many ways remarkable.

In the full-grown condition this species is much larger than Protamœba; and the false-feet are very long, slender, and much tangled together, as shown at 12 in the accompanying figure. At length these are drawn in; the

[1] Natural History of Creation, Appendix.

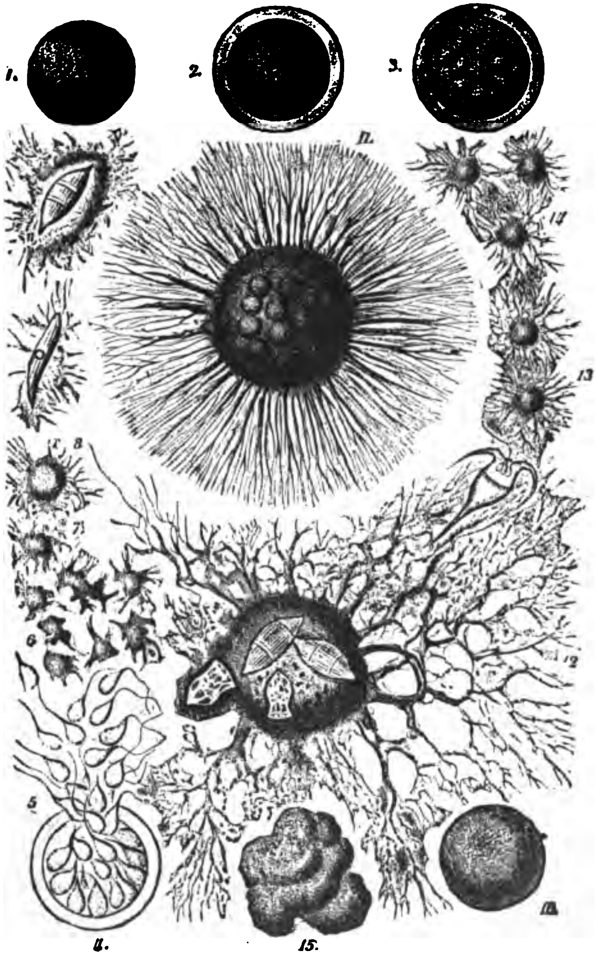


Fig. 11.—Protomyxya aurantiaca.

substances that have been taken in, but not digested, are all forced out of the body; it becomes covered with a toughish skin, spherical and motionless, as shown at 1; then the inner portion of the sphere draws together, as shown at 2, into a smaller sphere a little within the one just described, and this inner sphere soon breaks up into very many exceedingly small ones seen at 3.

These gradually grow pear-shaped (4), and at length break out through the covering-skin, and swim away through the water by means of slender tails (shown at 5) spun out of their jelly-like substance at the smaller end. After about a day of this free-swimming life the slender tail is drawn in, and the animal becomes extremely like a Protamœba (6, 7). But one more change needs here be followed: two or more of these Protamœba-like animals meet, melt into one, and that one sends out the long, interlacing false-feet shown in 12. A strange life-history, yet not so strange but that it is very closely followed by the plants of a humble group,[1] which take in their food, and creep about, which even melt together into one, in the same marvellous way as the moneron just described.

---

[1] The myxomycetes.

So indistinct is the partition between animals and plants, that the great German naturalist and microscopist Ehrenberg, the founder of the zoölogy and botany of the microscopical forms of life, was often misled in regard to the nature of his favorite objects of study. Although his researches lasted a third of the way into the present century, he was to the last so much in the dark in regard to the matter of a well-known little organism (now recognized by all as a plant[1]), that he described it as having a mouth, an eye, and several stomachs.

It has seemed worth while to go into so much detail in regard to these lowest organisms, because they illustrate, better than any thing else can, the nature of the animal and the vegetable cell; and from some kind of a cell each animal and plant originates.

In the case of animals, the cell which is to grow into the fully developed individual is called the ovum, or egg; and generally it is not less simple in the highest than in the lowest animals, or, as Professor James Orton says, —

"At the outset, all embryos, from the sponge to man, are indistinguishable from one another. They are mainly drops of fluid a little more transparent on one side than the other; and in all cases this almost homogeneous

[1] Volvox globator.

globule must develop three well-defined parts, — a germinal dot, germinal vesicle, and yolk." [1]

Now, these parts correspond very closely with the nucleolus, the nucleus, and the protoplasmic cell-contents of the amœba; and a figure drawn from one of these objects might readily be taken to represent the other. More than this, the egg in its earliest stages not only *looks* like an amœba, but it also *acts* like one; for all eggs of animals in this earliest stage move about in the same sort of creeping way in which an amœba moves.[2]

FIG. 12. — Mammalian Egg.

The same is true of the white corpuscles, or cells, found in the blood of all animals; and in the white blood of sea-snails the corpuscles have even been seen taking food, just as so many amœbas would.[3]

Now, just as the amœba begins the process of self-division by halving its nucleus, so the egg, in every case, shows the beginning of the process of forming an embryo [4] by halv-

[1] Comparative Zoölogy, p. 201.

[2] Haeckel's Evolution of Man, i. p. 134. [3] Ibid., p. 145.

[4] The germ, or rudimentary animal, before birth.

ing its germinative vesicle, and then the rest of the yolk. While this first halving of the yolk is going on, or as soon as it is finished, each of the newly formed portions is again divided into two, and so on till the whole contents of the egg is changed into a mulberry-like mass of little globular cells, much as the contents of the large, thick-walled sphere in the orange-colored moneron (Protomyxya) already described, became broken up into pear-shaped cells.

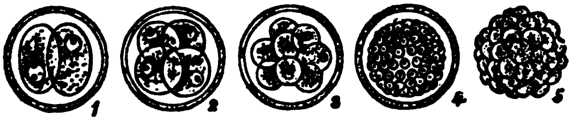


FIG. 13.—Segmentation and Formation of the Mulberry Stage in Vertebrate Egg.

Up to this point the process of development has been substantially the same for all animals:[1] the story as told is equally true of an amœba, a sea-urchin, a tape-worm, an oyster, or a frog.

But, while the close similarity in the process of development of *all* animals stops short at the period when the mulberry-like appearance has been reached, the sub-kingdoms above the pro-

[1] Except some of those very lowest forms which Haeckel ranks below protozoa, the "protista."

tozoa continue to closely resemble one another at the next succeeding step. This step forms what Professor Haeckel calls the "gastrula-stage."

"It seems perfectly certain, then, that, if the mulberry-stage constitutes a first landmark in the development of the animal kingdom at large, no less does the gastrula-stage form a second resting-place in the track of life: since, as Haeckel and other embryologists have shown us, the gastrula-stage of development (with its primitive

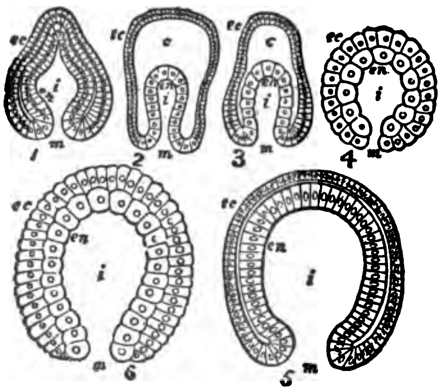


FIG. 14. — Gastrula Stage in Animals of Different Sub-Kingdoms.

mouth [*m*], body-cavity or stomach [*i*], and double layers [*ec* and *en*]) occurs equally in the zoöphyte (5) and worm (1), is as typical of the star-fish (2) as of the crustacean (3), and aids as materially in the formation of the snail (4) as in the development of the vertebrate (6). After its gastrula-stage, each animal form may be said to

assume the special features of the group to which it belongs." [1]

Within the limits of each sub-kingdom, the process of embryonic growth and development, onward from the gastrula-stage, is not less striking in its uniformity. To give even a hasty account of the process would involve many pages of description, and it will here suffice to state only a few interesting facts in regard to the strong likeness that prevails among the embryos of vertebrates. Says Von Baer, the father of embryology, —

"The embryos of mammalia, of birds, lizards, and snakes, probably also of chelonia,[2] are in their earliest states exceedingly like one another, both as a whole, and in the mode of development of their parts; so much so, in fact, that we can often distinguish the embryos only by their size. In my possession are two little embryos in spirit [alcohol], whose names I have omitted to attach; and at present I am quite unable to say to what class they belong. They may be lizards, or small birds, or very young mammalia, so complete is the similarity in the mode of formation of the head and trunk in these animals. The extremities, however, are still absent in these embryos. But, even if they had existed, in the earliest stage of their development we should learn nothing; for the feet of lizards and mammals, the wings and feet of

---

[1] Wilson's Chapters on Evolution, pp. 186, 187.

[2] Turtles and tortoises.

birds, no less than the hands and feet of man, all arise from the same fundamental form."[1]

And not only is there noticeable this wonderful resemblance among the embryos of existing animals of the same sub-kingdom; but it also seems probable, according to Professor Louis Agassiz, — and it must be remembered that there have been few opponents of the development theory so illustrious as Agassiz, — that *all* embryos contain reminiscences of, or points of resemblance to, the full-grown, pre-existing animals of the same group. For example, if we find (as is the case), that, in the embryo of birds, the fore-limb or wing is for a long while much like the foot, this would be, according to Professor Agassiz's theory, a reason for at least supposing that the earliest birds, of previous geological ages, had fore-limbs more like feet than like the wings of birds of the present day.

In many cases, the study of fossil remains has proved beyond a doubt that the view just stated is a true one. But, in adopting this view, how difficult it is to avoid coming to the conclusion that existing animals at some period of their history resemble the most nearly allied

[1] Quoted by Darwin, Origin of Species, p. 387.

among those which preceded them, simply *because the present kinds are descended from those earlier ones*, or at any rate both are descended from common ancestors! And this ready explanation clears up very many difficulties in the same way that one is relieved to find that a strong resemblance between two people arises, very naturally, from the fact (of which we were not at first aware) that they are relatives.

Professor Haeckel has strongly emphasized the doctrine, that, in all cases, *the history of the development of each individual portrays the history of the development of its tribe* from its origin, back amid the imperfectly recorded events of the geological past, till now. According to this view, then, the presence of the gastrula-stage in the development of individuals in so many sub-kingdoms suggests that all the higher of those sub-kingdoms are descended from a lower one. If we look for a common ancestry for plants and animals, the almost indistinguishable closeness of resemblance between the lowest forms of either kingdom offers a substantial basis for such an hypothesis. So little has as yet been done toward a minute application of Haeckel's law of embryology to the life-history of plants, that it will not be possible to trace the subject out in the present chapter. Pro-

fessor William Trelease[1] has kindly furnished the authors with a brief sketch of the matter, which is necessarily so much more technical than the main portion of this book, that it has seemed best to insert it in the Appendix.[2]

One subject more remains to be treated in connection with embryology; that is, the existence of rudimentary or abortive organs.[3] It has long been known to naturalists, that many animals and plants are possessed of members, parts, or organs of which they make no use; although such organs usually have their counterparts in useful structures of the same kind, — either in individuals of the same species but the opposite sex, or in other related genera, families, or orders. How such a change as the partial loss of an organ might prove beneficial to an animal has already been alluded to in the case of the tuco-tuco, which seems to be gradually losing its eyesight, and will be better adapted to its underground mode of life when relieved of the inflammation of the eyes with which it is now frequently troubled. Snakes and many

[1] Professor of botany at the State University, Madison, Wis.

[2] See Appendix.

[3] Such members of an animal or plant as are imperfectly developed, and of no use.

lizards have a body too narrow to admit of the use of two lungs, and accordingly we find them with only one active lung and the remnant of another. So, too, the horse (as will be seen in the following chapter) has rudiments of two toes on each side of the foot, besides the one toe on which the hoof is set, which alone is of use to him.

In the above instances, it is plain enough that the animal would have gained in the struggle for existence by losing the organs which have in each case become aborted; and we may be sure that natural selection would operate powerfully to perpetuate any variations which at first tended toward bringing about the degenerated condition. Multitudes of instances are known; but only a few of the most curious and instructive can here be cited. The Greenland whale, when full-grown, has no teeth; but in the embryonic condition it has teeth in both jaws. Calves, before birth, have eye-teeth and cutting-teeth in the upper jaw; the boa-constrictor has rudiments of hind-legs and of hip-bones; many birds (as the ostrich) have only rudiments of wings; and among insects we find all the stages, from the possession of two pairs of wings fully developed, to the complete absence of wings.

It will be noticed, from what has been stated,

that some of these undeveloped organs show themselves only during the embryonic state: and there is one most striking fact of this kind; namely, that all vertebrate animals above fishes pass through one embryonic stage, during which there appear four distinct arches, or, pairs of semi-arches, of gristle on the neck, corresponding exactly in position and mode of growth to the gill-arches of fishes. These gill-arches in fishes are well known to every boy who has worked a fish-hook loose from the slender hoops on which the red gill-fringes are supported.

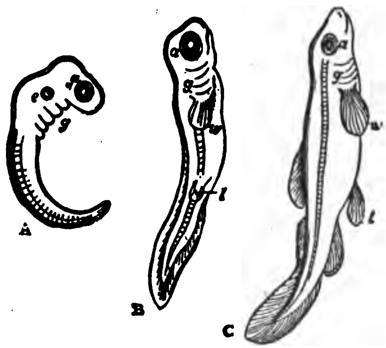


FIG. 15.—Embryonic Fishes.

At *A* in the figure is represented the embryonic fish at an early stage of its growth; the gill-arches being at *g*. In *B* and *C* the more

fully developed animal is seen, with the gill clefts and arches represented at *g*. An embryonic turtle, chicken, or rabbit so closely resembles the early condition of a very young fish, that the same figure *A* would fairly represent them all.

But what does the presence of these rudiments in all vertebrates (man included) in the early stages of growth mean? What can it mean, except that all vertebrate animals must look back to a common ancestry? For the facts of embryology and the existence of rudimentary organs, no more than two explanations can be offered. Either the possession of common characteristics in the whole series of animal sub-kingdoms, and the circumstance that each animal in the successive periods of its early life-history passes through stages in which it is extremely similar to full-grown individuals of lower forms, indicate a relationship on the part of the higher form to the lower ones, or they do not. In the latter case we must conclude that these resemblances were deliberately created for some incomprehensible purpose. But then we should be forced to attribute imperfection to the plans of the Creator, since we find that in many instances the resemblance of the early stages of an animal to lower forms is highly disastrous to the animals.

The free-swimming stage through which young oysters, for example, pass, is the cause of a very large proportion of every generation of young becoming destroyed; so that it is only by their extraordinary breeding-powers that the number of oysters is maintained. So, again, the retention of embryonic, rudimentary organs and conditions after birth is the cause of many disagreeable and injurious monstrosities.[1] Or an undeveloped organ may, while of no use in itself, become the seat of disease; notably so in the case of the abortive human tail, the coccyx, a little series of three, four, or five joints at the end of the backbone, which are by no means indispensable, but which sometimes become the seat of so painful a neuralgic condition, that they have to be removed by amputation.[2]

And again: there is found in man a slender, blind tube (the worm-shaped appendage) attached to the region where the large and the small intestine are joined together. In many of the lower animals, as, for instance, in the apes, which live on vegetable food, this tube is a large and useful part of the intestine; but in man, in its abortive condition it is apparently

---

[1] Such, for example, as hare-lip.

[2] Ziemssen's Cyclopædia of Practical Medicine, vol. x. pp. 559, 560.

worse than useless, since it not infrequently becomes the cause of death from the lodgement of any small substance (as, for example, a raisin-seed or a cherry-stone) in the appendage. Such a mishap as this lodgement is always likely to be followed by violent inflammation, from which, as just stated, death often results.

In summing up the embryological evidence as here recited, it will be remembered that all of the sub-kingdoms of animals above the lowest one have been shown to resemble each other in a most interesting way by exhibiting, first a mulberry-stage, and then a gastrula-stage, at an early period of their life-history. All vertebrates have been shown to exhibit their common origin from some fish-like form by the possession of gill-arches in the embryo. A few other abortive organs have been mentioned, among them some so injurious to their possessor as to forbid the supposition that they were designed by a benevolent Creator. Only here and there a link out of the long chain of evidence can be given in a statement so condensed as the present one must be made. But it is evident, from the brief statement of facts embodied in the earlier part of the chapter, that, on the whole, the process of development of the embryo is what we should expect it to be if the theory

of descent were true; while such facts as the free-swimming condition of the young oyster, and the possession of the occasionally injurious rudiment of a tail, and of the worm-shaped appendage in man, are inexplicable by any other theory. We must, in short, believe with Professor Haeckel, *that the development of every individual is a brief repetition of the development of its tribe.*

CHAPTER VII.

THE TESTIMONY OF GEOLOGY.

BEFORE the evidence of geology for or against evolution can be summed up, it may be well to outline a few of the facts of paleontology, or the ancient life-history of the earth.

It is admitted by geologists that our globe was in a melted conditicn for a time after it assumed its present shape of a flattened sphere. Of course no life of any kind conceivable by us could have existed on its surface till after the latter had become solid, and then had cooled to a temperature below that of boiling water. How long a time has elapsed since this hardening of the earth's crust took place is a matter still under discussion:[1] indeed, the estimates vary all the way from two hundred millions of years to ten millions. Much confidence has

[1] A summary of recent opinions on this subject may be found in Geikie's Text-Book of Geology, pp. 54-56.

been placed in Sir William Thomson's limit of one hundred millions of years as the greatest length of time that can be allowed; and both the method which he employed, and his well-known ability to deal with problems of this character, render Thomson's estimate at least as authoritative as any that has yet been made. It is quite impossible to realize what is meant by a hundred million years, or what geological changes might be produced in such a period of time. Let us see what might be done in one direction alone by geological forces acting throughout such a period. Coast-lines have been known to rise at the rate of nearly four inches a year: suppose such an elevation to take place for a hundred million years, at the very gradual rate of a tenth of an inch per year, and we shall have an upheaval of almost *one hundred and sixty miles above sea-level!*

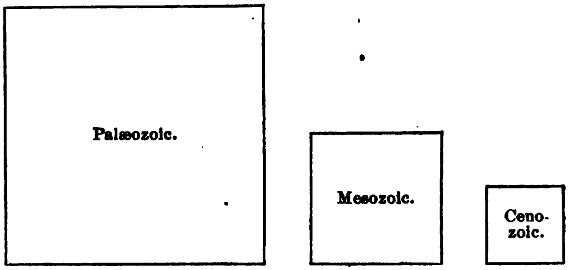
Whatever may be the length of time during which the condition of the earth's surface has been such as to allow the existence of life upon it, geologists, excepting those who would reckon the ages of the cenozoic together, calling the whole but one, are agreed upon the following divisions into eras of life, and ages under them: —

ERAS.	AGES.
CENOZOIC, or era of newer forms of life.	1. Quaternary, or age of man.
	2. Tertiary, or age of mammals[1] and of angiosperms.[1]
MESOZOIC, or era of intermediate forms of life.	Age of reptiles and of cycads.[1]
PALÆOZOIC, or era of ancient forms of life.	1. Carboniferous, or age of amphibians[1] and of acrogens.[1]
	2. Devonian, or age of fishes.
	3. Silurian, or age of mollusks[1] and of algæ.[1]
EOZOIC.[2]	Eozoic, or age of beginnings of life.

The time-ratios of the palæozoic, mesozoic, and cenozoic eras, are, according to Professor Dana,[3] 12 : 3 : 1; that is, if the total time from the beginning of the silurian to the present

[1] Defined in Appendix.
[2] The life-history of the Eozoic is not, and may never be, clearly made out.
[3] Manual of Geology, p. 591.

were estimated at forty-eight million years, the palæozoic would occupy thirty-six million, the mesozoic nine million, and the cenozoic three million. Or, to put it in the form of a diagram:—



Of the life of the eozoic very little is known.

The silurian age began[1] with no animals higher in the scale than shell-fish. The seas swarmed with these and many other low forms of life; but backboned animals do not seem to have existed, and no plants higher than sea-weeds remain to us in the rocks deposited at that early time. Land-plants first occur in rocks formed near the close of the silurian age,

[1] It is always to be understood that when the statement is made, that any form of life began at a certain time, it means that the *earliest known fossils* occur in rocks of that age.

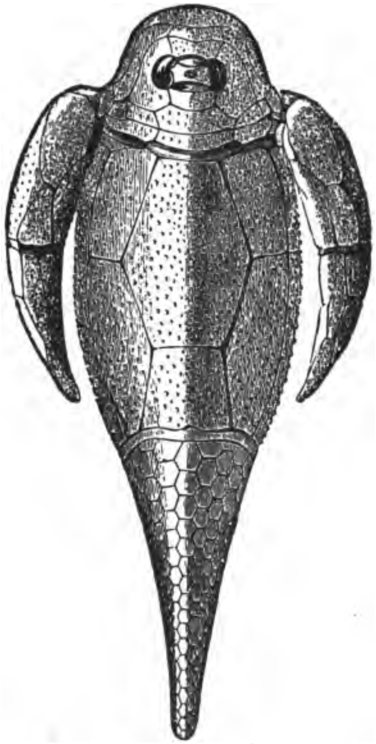


FIG. 16. — One of the Earliest Fishes, Pterichthys Milleri.

and fishes of uncouth forms, also, have been preserved from this time.

In the devonian age the presence of fishes became a leading characteristic of the seas; corals, too, which were abundant in the waters of the preceding age, became extremely numerous; and land-plants were common. Some of these were sturdy trees, but all were of comparatively low organization.

In the carboniferous age a further advance in animal life occurred; namely, the introduction of the first vertebrates higher than fishes. These earliest amphibians and reptiles were respectively frog-like animals and great sea-lizards. Plants of most luxuriant growth flourished among the extensive marshes which covered much of Europe and an immense area in Eastern North America. But though the forests of carboniferous time in their strange luxuriance exceeded any that have since covered the earth, our highest two divisions of plants were still lacking, and it was not till the reptilian age that these appeared.

The reptilian age was characterized, not only by the advance in plant-life just mentioned, but also by the advent of hosts of strange lizard-like forms. There were reptiles that swam in the sea, reptiles that crawled and that walked

along the beach, and reptiles that flew like so many gigantic bats. The Atlantosaurus, a reptile of this age, whose fossil remains were discovered by Professor O. C. Marsh, probably exceeded in size any known animal. It had a length of about a hundred feet, and a height of thirty feet or more. So characteristic were the peculiar plants of this age, called cycads, that it has even been known as the age of cycads.

In the mammalian age, mammals for the first time become predominant; and the earth was peopled with such an assemblage of animals of this group as is not even approached by the great fauna of South Africa at the present day. Among plants, all the great groups now found were represented.

In the earlier part of the age of man, the fauna and flora differed greatly from those now existent; but it will not be necessary to say more of the matter in this place, since it will again be referred to in a later chapter.

Some of the facts just stated may be most clearly represented to the eye by the following diagram, altered from Dana's "Manual of Geology."[1]

[1] P. 139. Some changes have been made in the names of the groups.

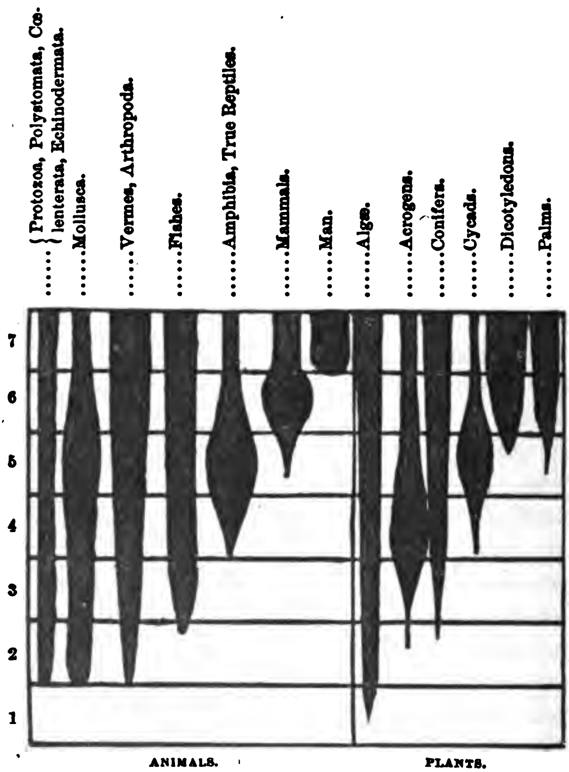


DIAGRAM OF PROGRESS OF LIFE.

1. Archæan Time.
2. Age of Invertebrates, or Silurian.
3. Age of Fishes, or Devonian.
4. Carboniferous Age.
5. Age of Reptiles, or Secondary.
6. Age of Mammals, or Tertiary.
7. Age of Man, or Quaternary.

In explanation of the diagram Professor Dana says, —

"The horizontal bands represent the ages in succession: the vertical correspond to different groups of animals and plants. The lower end of each vertical band marks the time when, *according to present knowledge from fossils*, the type it represents began; and the varying width in the same band indicates the greater or less expansion of the type."

The grand question which the student of organic evolution has to ask of the science of palæontology is, "Does the general succession of life-forms on the earth tend to corroborate the doctrine of descent?" The answer to this question must be given somewhat at length.

At the outset, one of the most striking facts to be gathered from the diagram just given is the very late appearance on the earth of mammals in general, and in particular of man; the latter, according to the time-ratios already cited, having appeared only after $\frac{15}{16}$ of the time has elapsed from the beginning of the palæozoic to the present.[1]

Again: the reptiles and amphibians, and the fishes, which respectively constitute the next

[1] Man may date back to the beginning of the cenozoic. See Chap. IX.

two steps downward in the scale of animal existence, appear farther and farther back toward the beginning. That the lowest four subkingdoms, together with the mollusks, worms, and arthropods, should seem to have been introduced abruptly and at the same time, apparently furnishes a decided objection to the origin of the higher forms from previously existent lower ones, as the development theory assumes. But to this objection there is a very easy answer; namely, *that we do not know what the earliest forms of life were.*

The eozoic rocks of the earth, so far as they are now known, show evidence of having been intensely heated since they were deposited; and they have, as a result of crystallization or even melting, become so greatly changed in their structure, that it would indeed be strange if any fossil could have been preserved in them.

It seems, however, that, even from these greatly altered rocks, the remains of one organism, the *Eozoon Canadense*, have been made out.[1] This animal, apparently, — for the nature of the objects generally known as Eozoon fossils is still much discussed, — was a protozoan of but

[1] Carpenter's The Microscope and its Revelations, pp. 587–593; Dana's Manual of Geology, p. 158.

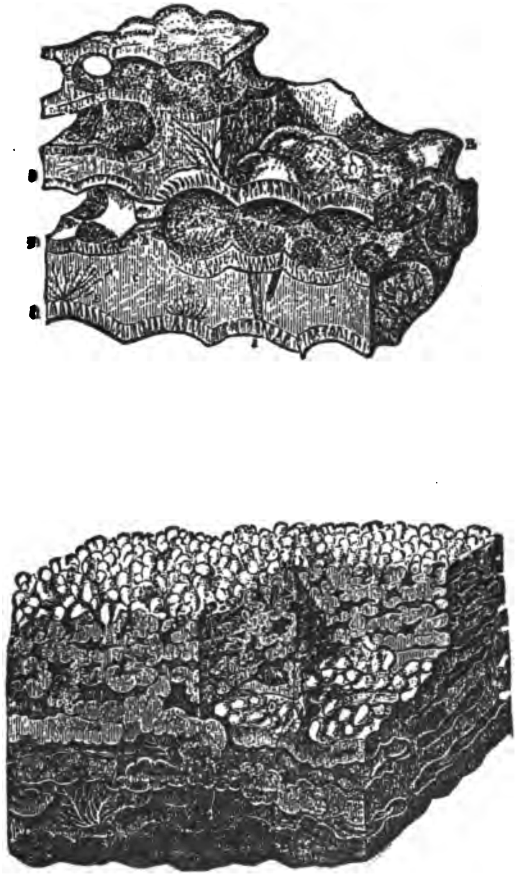


FIG. 17.—Eozoon Canadense.

little, if any, higher organization than the amœba. It possessed, however, the power of secreting about itself thin layers of shell, pierced with minute cavities, by means of which the whole living mass was connected together. In its mode of growth and of shell-formation the Eozoon is somewhat allied to living and to fossil members of the class Rhizopoda, — microscopic creatures which constitute a great part of the life found in the depths of the sea.

Common chalk is a rock composed mainly of the shells of many kinds of foraminifera, — representatives of the rhizopods.

It has been ascertained that the present sea-bottom is in many cases slowly building up by the deposition of foraminiferal shells, forming a chalk-like material. Most of those limestones of the world which lie embedded between layers of other kinds of rock are composed mainly of the shells of rhizopods. Now, such limestones (that is, of this interbedded character) are found in abundance in the eozoic rocks;[1] and among the same rocks are found many layers of graphite [black-lead].[2] This is a most important and

[1] Dana's Manual of Geology, p. 158.

[2] Dr. Dawson estimates the total amount in one band of limestone in the Ottawa district as equivalent to twenty or thirty feet of graphite. At St. John he thinks he has found

suggestive fact; for graphite is in some instances known to have been produced from fossil remains of plants; while *there is no proof that it has been formed, or could naturally be formed, out of any thing but animal or plant remains.*

Even if the animal nature of the structures known as Eozoon should never be established, there are ample proofs of the existence of a wealth of life in the Archæan rocks, from the

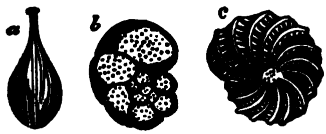


FIG. 18.—Foraminifera.

presence of the above-mentioned limestones and graphites. Since the first life of the eozoic era very likely flourished in the waters of an ocean still heated to a high temperature by the slowly cooling crust of the earth, it would seem highly probable that the first plants were microscopic seaweeds, since small algæ (and no other plants) are found in the waters of hot-springs at the present day, even where the heat is as high as

---

a fibrous structure in the graphite, an evidence of its having been formed from land-plants.—GEIKIE's *Text-book of Geology*, p. 639.

200° F., or within twelve degrees of the boiling-point of water.[1]

For the same reason (if there were no others assignable), protozoans must probably have been the first animals of the eozoic. But, since the eozoic lasted for an immensely long period before the beginning of the palæozoic, there may well have been time for the development, from protozoan ancestors, of any or all of the low forms of life found at the beginning of the silurian age. There is, then, in the known facts regarding the kinds of life found at the beginning of the palæozoic, no contradiction of the theory of descent.

A strong argument in favor of the theory is based upon the fact, that, as a rule,[2] the lowest animals and plants of each type are the first introduced, and that the subsequent history of the type is one of progress, both in the number of species and individuals, and in the complexity of organization or the perfection of structure, of the animal or plant.

The period of highest development of each group is usually followed by a concluding period of dwindling away, in which the numbers diminish, and the species become dwarfish, —

---

1 Dana's Manual of Geology, pp. 611, 612.

2 Subject to a few exceptions.

changes mainly due to the influence of less favorable conditions of life. Any class of animals may fairly be said to advance in the scale of being, when out of aquatic forms it first gives rise to terrestrial ones. Of such advances a most striking one took place in the beginning of the carboniferous age, extending through many groups of animals, and over wide regions, both in the eastern and the western continents.

The first mollusks were of a type so closely allied to that of worms, that many of the ablest zoölogists now follow the example of Professor E. S. Morse in ranking them as members of the sub-kingdom Vermes.[1] In this case we have an illustration of the important general law, that *the earlier members of any group of animals are frequently of comprehensive types;* that is to say, they resemble the members of two or more later groups, which may be very distinct from each other.

The appearance of such animals as the Archæopteryx affords a perfect illustration of this law.

This was a bird whose fossil remains were first found at Solenhofen, Bavaria, in 1861.

---

[1] For a full account of the matter, see Professor Morse's paper, Proceedings Boston Society of Natural History, vol. xv. March 19, 1873.

"In 1879 Professor Carl Vogt made a communication respecting a fresh specimen of this ancient bird, found in the same deposits which afforded the previous specimen.

FIG. 19.—Fossil Remains of Archæopteryx.

The new specimen was singularly complete; and its wings were unfolded, as if death and fossilization had overtaken it in the act of flight. Its examination revealed certain startling features, which only serve to confirm in an un-

mistakable manner the thoroughly 'intermediate' nature of this animal. Its upper jaw bore two small conical teeth; the breast-bone is 'reduced to zero;' and, whilst its arm-bones 'present no features peculiar to reptiles or to birds,' its hand[1] can be compared neither to that of a bird, nor to that of a pterodactyl,[2] but to that of a three-toed lizard. 'If the feathers had not been preserved,' says Vogt, 'no one could ever have suspected, that, from the examination of the skeleton alone of *archæopteryx*, this animal was furnished with wings when alive.' Head, neck, chest and ribs, tail, shoulder-girdle, and arm or wing, are all built on a reptilian type; the haunch is more reptilian than bird-like; but the hind limbs are those of a bird. The reptile characters unquestionably predominate in the skeleton, just as the bird characters come to the front in the feathers.

"Professor Vogt strenuously asserts, that a study of *archæopteryx* shows that it is neither bird nor reptile, but that it is a decided 'link' between the two classes."[3]

The following figure may give an approximate idea of how the living Archæopteryx looked.

Many other instances might be given of animals more or less perfectly intermediate between birds and reptiles, such as the birds found in Kansas rocks of the mesozoic era by Professor O. C. Marsh. These birds had double concave vertebræ (as reptiles have), and forty or more

---

[1] Or end of the wing.
[2] A kind of fossil flying-lizard.
[3] Wilson's Chapters on Evolution, p. 159.

teeth in the lower jaw alone. Again: the earliest fishes were in some respects intermediate between fishes and reptiles; so that one could hardly look at the figure of Pterichthys already given, without being forcibly reminded of such reptiles as the marine turtles. Others of the earliest fossil fishes with strongly reptilian char-

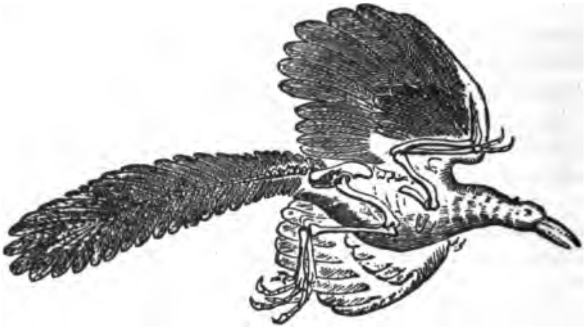


FIG. 20. — Archæopteryx restored.

acteristics closely resembled their degenerate descendants of the present day, the gar-pikes of our Western lakes and rivers. It is, says the great zoölogist Rütimeyer, only their retreat into fresh water that has saved these gar-pikes from the fate of extinction that has befallen their marine ancestors of palæozoic seas.[1]

[1] That is, by becoming acclimated to fresh water, they have escaped the far more severe struggle for existence that goes on in the sea.

The great sea-lizards of the reptilian age, one of which is figured below, seem to have had shark-like intestines, and, from this fact and some others, to have been related to both lizards and fishes.

The early nerve-winged insects, which are closely related to the modern dragonflies, had certain characteristics of the grasshopper of the present day.

How can facts of this kind be more naturally interpreted than by considering the modern *less comprehensive types* to be descended from the elder *more comprehensive* one, which by variation has given rise to two or more later groups? It is true there are many exceptions to the general rule, that the first introduced members of each type are its lowest representatives. There is, however, in many of these cases, reason to suppose that

Fig. 21.—Fossil Remains of a Sea-Lizard.

the exception is only apparent, and would disappear if the life-history of the earth were more perfectly known; but there are others which are probably not to be explained by any knowledge which the paleontologist can acquire. Important and puzzling as they may be, these exceptions are not sufficient to prevent the general conclusion, that the law of life has been progress, by modified descent, from lower to higher forms. Illustrations of this law additional to those already mentioned may be found in great numbers in any work in which paleontology is at all fully treated.[1]

From the protozoans of eozoic time to the invertebrate sub-kingdoms of the lower silurian; from these to the fishes of upper silurian time, then to the amphibians and the true reptiles of the carboniferous, to the first birds of the reptilian, and the mammals of the same age; from these lowly quadrupeds up to man, — how closely this ascending scale of being corresponds to what the development theory would lead us to expect!

In the series of fossil plants, the general law of progress is exemplified; since the earliest

---

[1] Nicholson's Ancient Life-History of the Earth is one of the most compact and readable elementary works.

found are algæ, and it is only at a very late period that dicotyledons appear.

That the law cannot among plants be verified nearly as much in detail as among animals is no doubt due in part, if not entirely, to the fact that we have a far less perfect paleontological record of plants than of animals; for plants have no parts which are as durable as the bones and teeth of vertebrates, the shells of mollusks, or the limy skeletons of corals. Then, too, if we except the seaweeds (which are preserved with difficulty), the greater part of the world's flora is terrestrial. On the other hand, the greater bulk of its fauna is now aquatic, and this predominance of aquatic animals was much more pronounced in the earlier geological ages; so that the chances are far more in favor of a comparatively full representation of extinct forms of animal than of plant life.

Lichens and toadstools are of so low organization, that they might be expected to appear very early among fossil plants. It is not strange, however, that their fossils are late to appear, and very rare; since their lack of woody fibre, and their terrestrial habits, must have rendered it extremely difficnlt for their remains to be preserved.

In the cycads (one of which is here figured)

we have a striking example of a comprehensive type. They had the general form of palms, the mode of unrolling the leaf from the bud that is characteristic of ferns, but had wood and flowers (ripening into cones) very much like the cone-bearing evergreens, such as pines and spruces.

Now, the idea may not unnaturally occur to

FIG. 22. — A Cycad.

any one, on looking over any statement of the succession of forms of life on the earth, that perhaps the reason why ordinary flowering plants (angiosperms) are not found at an earlier date than is assigned them is because the earth's surface was not fit for them; the soil, the climate, or both, having been unsuited to their growth.

The same kind of argument might be urged, with still greater apparent reason, in the case of animals.

But it is in the power of the geologist to transport himself back in thought, even to the scanty North-American continent and the scattered archipelago of Europe in the eozoic era. From the many thousands of analyses of minerals and rocks made by skilful chemists, from the known thickness of the various strata of rocks of all the geological ages from eozoic time till now, and from the microscopical study of these rocks, it is possible to decide approximately under what conditions they were formed. It would seem to be pretty clear that most types of plants might have flourished in some part of the earth during or at any time since the Devonian age. There may have been too much carbonic acid gas in the atmosphere to allow birds or mammals similar to those now living to occupy the earth's surface till the close of the carboniferous age.

Why each type of animal or of plant life should not have appeared on our planet as soon as it could have existed is a question to which no answer can be given, except on the basis of the doctrine of descent. But this theory readily explains all such cases; for obviously no animal or plant could occupy any part of the earth's surface, no matter how fit the conditions were for its existence, until the type in question could be developed from pre-existing species.

Many common flowering plants (angiospermous dicotyledons) now seem fully as capable as are evergreen trees of living under disadvantageous conditions; and so would it not have been quite possible for ordinary hard-wood trees to flourish side by side with the trees of the pine family that lived at least as far back as the beginning of the carboniferous age? The introduction of deciduous trees at this early period would have increased the time of their occupancy of the earth's surface to something like four times the length at which it is now estimated.

But what possible reason could be put forward by the believer in special creations to account for this great apparent waste of opportunities?

Some other classes of facts, derived from the study of geology, and confirmatory of the development theory, remain to be stated. Among the most striking of these is the well-known resemblance often noticeable between the present and the fossil inhabitants of any region. It was, among other things, the observation of this resemblance in South America, that led Mr. Darwin, after his return from a voyage round the world, to insist on this "law of the succession of types" on "this wonderful relationship in

the same continent between the dead and the living;" for in South America there are found fossil remains of the armor of gigantic extinct animals which bore a striking likeness to the existing armadillo, which occupies a large extent of the same continent, ***but is found nowhere else in the world.***

Huge sloths also, closely allied to those now living in South America, are abundantly represented there by their fossil remains. The fossil mammals of Australia, like the living ones, are marsupials;[1] and an equally close resemblance is found to exist between the remarkable extinct and recent birds of New Zealand. The occurrence of such likenesses is indeed worldwide.

The explanation of these facts is certainly not to be found in any incapacity of the regions to support other forms of life than those which have characterized them for so many hundreds of centuries.

The animals and plants of Europe have in many other parts of the world, as already mentioned, proved themselves easily capable of driving out the native species. From this strange fact the ready conclusion is, that the present

---

[1] Animals which carry the young in a pouch.

fauna and flora of countries resemble the fossil ones, as offspring always resemble parents. When the native productions are as easily displaced by foreign immigrants as they are in Australia and New Zealand, it can only be because the former have long been protected by some geographical barrier from competition with more advanced forms of life.

And now, before leaving the subject of the geological evidence for the doctrine of descent, a case more striking in its confirmation of the theory than even that of the Steinheim snails or the ammonites must be cited. It is that of the series of transitional forms to be found among the remains of fossil horses.[1] The modern horse has on each foot, as all are aware, but one toe, — the third. Two other toes are represented by rudiments in the shape of two slender bones, the "splint-bones," — one on either side of the leg, — reaching down nearly to the pastern-joint, and sometimes each bearing a little hoof. Rudiments of two other toes still are sometimes found to occur as bits of gristle or cartilage at the base of the splint-bones.

Going back in the history of the horse family as far as the mammalian age, we find that

[1] Dana's Manual of Geology, pp. 504–507; article *Horse*, by Professor O. C. Marsh, in Johnson's Cyclopædia.

horses, *Eohippus* and *Orohippus* (Fig. 23, F F′), then existed, and that they had four usable

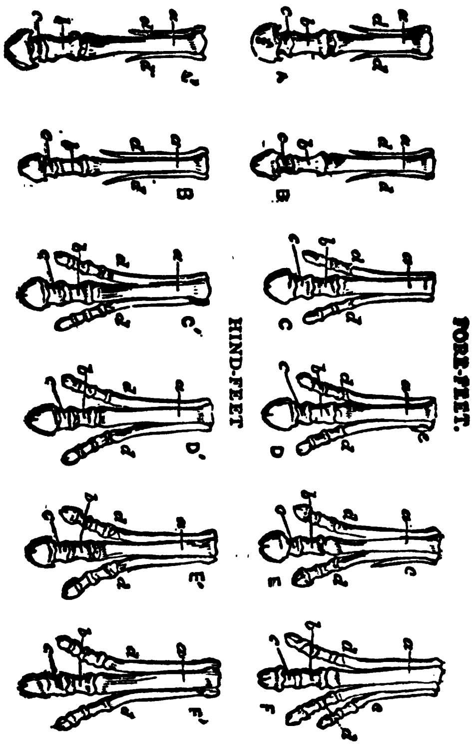


Fig. 23.—Fore and Hind Feet of the Modern Horse and of Fossil Horses.

A. Modern Horse.
B. Pliohippus.
C. Protohippus and Hipparion.
D. Miohippus and Anchitherium.
E. Mesohippus.
F. Orohippus.

a, cannon-bone; *b*, pastern; *c*, coronary bone; *f*, coffin-bone } of third finger and toe.
d, *d*, second and fourth finger and toe,
e, little finger.

toes, with the rudiment of a fifth (in the case of *Eohippus*), on the fore-foot, and three on the hind-foot.

In the number of toes, then (and in other respects besides), these first-known representatives of the horse family resembled ordinary quadrupeds far more closely than does the horse of to-day.

Then, in the middle part of the age, we find that there were horses (*Mesohippus*) with one rudimentary and three useful toes on the fore-foot, the middle toe being much the largest. In the latter part of the age, there flourished still another genus of horse (*Hipparion*), with three toes on the fore-foot, but only the middle toe useful; the two outside of it, like the dew-claws in cattle, not touching the ground. Still another genus (*Pliohippus*) has the rudimentary toes intermediate in development between those of *Hipparion* and those of our domestic horse.

The latter is also represented, among the fossils of the region where the last two genera above mentioned have been found, by a genus nearly or quite the same as the modern horse.

There is to be found in all, according to Professor O. C. Marsh (the highest authority on this subject), among the fossils of Wyoming, the Upper Missouri region, the Rocky-Mountain region, and Oregon, a series of not less than thir-

ty intermediate or transitional forms. These[1] make thoroughly clear the process of modified descent by which the advance was made from the five-toed *Eohippus* to the horse of to-day.

Nor is the marked progress throughout the series confined to the solidification of the foot, and consequent increase in capacity for speed. It is also noticeable in the gain in size,[2] the lengthening of the neck, and the modification of the skull.

That such a closely linked set of forms, illustrating the progressive development of an animal of as high grade and greatly specialized powers as the horse, from so comparatively inferior an animal as the little *Eohippus*, should ever have been discovered, is all that the most sanguine believer in the development theory could have desired, and more than he could fairly have expected. Only a paragraph here and there, out of the vast body of paleontological evidence in regard to the theory of descent, has been cited in the present chapter. It would appear that the general drift of the evidence is greatly in favor of the theory in question, though there are not wanting cases

---

[1] Examples hardly less striking are to be found among the fossil horses of Europe.

[2] Eohippus was about the size of a fox.

in which the evidence seems contradictory. In these instances it is not unfrequently fair to assume that what appears to have been a sudden introduction of species was not really such, but seems so, only because the book of geological records was never complete, and much of what was once recorded has since been erased. "Links," it is often said, must (if the development theory be true) once have existed, and ought now to be producible. But in the first place it is certain that sometimes there never was any "link;" that is, the new species, or even genus, was produced abruptly from some other one, as in the case of the black-shouldered peacock, or of the brine-shrimps already mentioned. Even where there was once a graduated series of forms, must it not *usually* have been true that this series, transitory in its nature, would fail to become represented by fossils?

No domestic animal is more abundant than the dog, or more widely distributed; yet what probability is there that fossil remains are even now anywhere to be found which could conduct us back through a series of "links" to the dog's wild ancestors? And if we set the problem some hundreds of thousands of years (not to say millions) into the future, for the pale-

ontologists of those days to solve, does their work become any easier than it would be for us if performed at present?

Wherever the known incompleteness of the geological record[1] is insufficient to account for a difficulty, it becomes the believer in the development theory frankly to acknowledge that the riddle is too intricate to be solved by any means at his command. And yet, until an evolutionary rise of species had been assigned as an explanation of the succession of higher and higher animals and plants throughout the geological ages, what adequate reason for this progress of life could be given? Strike out from our present conception of the organic world, class after class, all notion of actual relationship by descent, and what have we left but a mighty list of extinct creatures whose rise, progress, and disappearance are far more unaccountable than that of the genii of the Arabian Nights!

---

[1] Darwin's Origin of Species, chap. ix.; Dana's Manual of Geology, pp. 600, 601; Nicholson's Ancient Life-History of the Earth, pp. 50, 51.

CHAPTER VIII.

THE TESTIMONY OF GEOGRAPHICAL DISTRIBUTION.

"WHEN an Englishman travels by the nearest sea-route from Great Britain to Northern Japan, he passes by countries very unlike his own, both in aspect and natural productions. The sunny isles of the Mediterranean, the sands and date-palms of Egypt, the arid rocks of Aden, the cocoa-groves of Ceylon, the tiger-haunted jungles of Malacca and Singapore, the fertile plains and volcanic peaks of Luzon, the forest-clad mountains of Formosa, and the bare hills of China, pass successively in review, till, after a circuitous voyage, of thirteen thousand miles, he finds himself at Hakodadi in Japan. He is now separated from his starting-point by the whole width of Europe and Northern Asia, by an almost endless succession of plains and mountains, arid deserts or icy plateaus; yet, when he visits the interior of the country, he sees so many familiar natural objects, that he can hardly help fancying he is close to his home. . . . There are also, of course, many birds and insects which are quite new and peculiar; but these are by no means so numerous or conspicuous as to remove the impression of a wonderful resemblance between the productions of two such remote islands as Britain and Yesso. . . . In the western hemisphere we find examples equally striking. The East-

ern United States possess very peculiar and interesting plants and animals, the vegetation becoming more luxuriant as we go south, but not altering in essential character; so that, when we reach the southern extremity of Florida, we still find ourselves in the midst of oaks, sumachs, magnolias, vines, and other characteristic forms of the temperate flora; while the birds, insects, and land-shells are almost identical with those found farther north. But if we now cross over the narrow strait, about fifty miles wide, which separates Florida from the Bahama Islands, we find ourselves in a totally different country, surrounded by a vegetation which is essentially tropical, and generally identical with that of Cuba. The change is most striking, because there is no difference of climate, of soil, or apparently of position, to account for it; and when we find that the birds, the insects, and especially the land-shells, are almost all West-Indian, while the North-American types of plants and animals have almost all completely disappeared, we shall be convinced that such differences and resemblances cannot be due to existing conditions, but must depend upon laws and causes to which mere proximity of position offers no clew."[1]

In these suggestive sentences Mr. Wallace lays before the reader one of the most interesting problems which the naturalist has to consider, — namely, the relations between the fauna and flora of a region and its geographical position and other characters.[2] The present

[1] Wallace, Island Life, pp. 3–5.

[2] Such as soil, climate, geological history, and so on.

chapter will try to point out the bearing which the teachings of zoölogical and botanical geography have upon the development theory. To do this, it will first be necessary to give an outline of the zoölogical regions into which the earth has been divided.

If we take an ordinary terrestrial globe, and study the arrangement of the great land-masses on its surface, we shall at once see that they are strung together in a very irregular way.

If a circle be drawn, with Behring Strait as a centre, so as to pass around the globe at a distance eighty degrees away from this centre, we shall find that the continental masses are either quite broken apart from each other, or (as in the case of the two Americas) are united, where this circle crosses them, by only a slender strip of land.

From the fact that the places where the continents are or have been separated from each other are indicated by the position of this circle which has just been described, it is called the *zone of fracture*. The only break between two continents, which does not lie somewhere along this circle, is the one at Behring Strait, its centre. A glance at the adjoining map[1] will make the whole matter plain.

[1] From Guyot's Physical Geography, p. 21.

It is clear enough, as the map shows, that the continents radiate away from Behring Strait as a centre. It is easy, too, to see that the circle

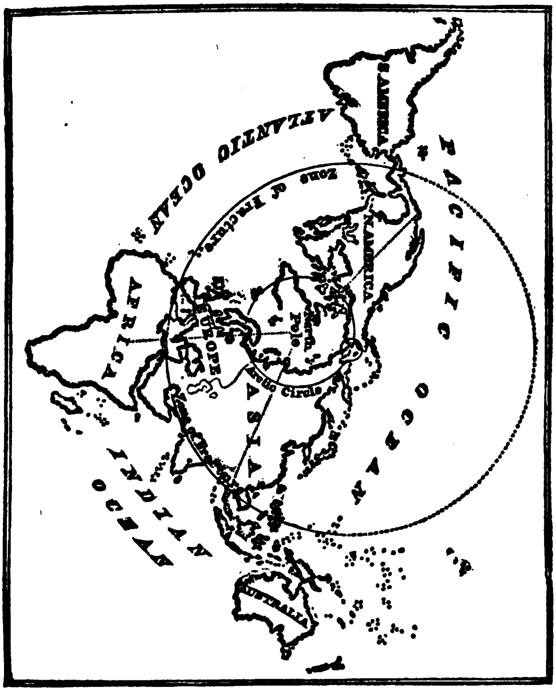


FIG. 24.—The Zone of Fracture.

marked "Zone of Fracture" corresponds to a real belt of separation between the continental land-masses.

Now, the zoölogical divisions of the earth, as described by Mr. Wallace in his latest work treating of this subject,[1] are six in number, as follows: —

I. PALÆARCTIC, *Europe*, with northern temperate Africa and Asia.
II. ETHIOPIAN, *Africa* south of the Sahara, with Madagascar.
III. ORIENTAL, *Tropical Asia* to the Philippines and Java.
IV. AUSTRALIAN, *Australia*, with the Pacific Islands, Moluccas, etc.
V. NEARCTIC, *North America* to North Mexico.
VI. NEOTROPICAL, *South America*, with tropical North America and the West Indies.

By comparing this list of zoölogical regions with the regions of fracture already described, it will be seen that the lines of division between the zoölogical areas in three cases — namely, through the Malay Archipelago, Behring Strait, and the Gulf of Mexico — correspond roughly with the zone of fracture. The two zoölogical boundaries which are to be met with outside of the zone of fracture are determined, — one by the Sahara Desert; and the other by the Soliman, the Hindoo Koosh, the Himalaya, and the Nanling Mountains. Now, the Sahara is as impassible a barrier for most quadrupeds as any

[1] Island Life, p. 52.

sea of equal size would be; the Himalayas are, as every schoolboy knows, the highest mountains in the world; and the Hindoo Koosh is a very lofty range. And so Africa is effectually cut in two by the Sahara; while tropical Asia is almost as completely shut off from the rest of the continent by the mountain ranges just mentioned, which entirely surround the bases of the two great peninsulas of British India and Indo-China.

If the animal population of the earth has spread gradually over its surface, each new species extending its limits over the whole adjacent territory, we should expect to find a certain degree of resemblance among the animals of all continents, or parts of continents, which are not separated by a natural barrier. On the other hand, when there is such a barrier, we should expect to find marked differences between the fauna on either side of it.[1] And just as we should expect to find things in this regard, so they actually are, as, I trust, the sentences quoted from Mr. Wallace at the beginning of the chapter have illustrated. The old idea, that

---

[1] Of course in every case allowance must be made for the possibility of obstructions or aids to the passage of animals back and forth, having arisen from changes in the earth's surface during comparatively recent geological time.

the types of animal life on the land are bounded by the zones of climate, has been finally abandoned. The boundaries of the zoölogical regions are rather determined by the presence of bodies of water, deserts, or lofty mountains, and *are in great measure independent of latitude and longitude.* In this connection it might very naturally be asked how it happens that Northern Africa is to be classed with the palæarctic region, although it is separated from Southern Europe by the Mediterranean. To this the answer is, first, that there is roundabout communication between Africa and other parts of the palæarctic region by way of the Isthmus of Suez, and second, that, in comparatively recent geological time, there has been *land communication* between the points of Africa and Europe now separated by the Strait of Gibraltar.[1] On studying the fauna of each of the six great zoological divisions and of the minor subdivisions of each, we shall find, that, on the whole, such animals as land-shells (snails, etc.) and freshwater fishes have the least range, that is are most strictly confined, each species to its own area. Fresh-water crustacea (such as the crawfish), insects, toads and frogs, and warm-blooded

---

[1] Schmidt, Descent and Darwinism, p. 224.

quadrupeds may range more widely, and reptiles even farther. Birds of some families have an almost world-wide distribution: the fish-hawk and the barn-owl are to be found ranging over the greater portion of every continent. It has already been stated in previous chapters, that the native animals and plants of a country are often less perfectly adapted to hold their own in it than are species from abroad. Couple this fact with the other fact just stated, that it is those animals that are best fitted to make long journeys, — namely the birds, that are found most widely scattered over the earth's surface, while the proverbially sluggish snail is often restricted to a single valley,[1] — and but one explanation of these facts of distribution is possible. We cannot avoid the conclusion that the wide range of birds and the narrow one of fresh-water fishes is due to the fact that the former can easily fly from region to region, while the latter can only traverse the fresh waters in which alone they can live.[2]

Experiments in fish-culture have demonstrated

---

[1] "Each valley [in the Sandwich Islands], and often each side of a valley, and sometimes every ridge and peak, possesses its peculiar species." — ISLAND LIFE, p. 299.

[2] This does not at all conflict with the statement made in a preceding chapter in relation to the occurrence of one spe-

that many species of fresh-water fishes (the European carp, for instance) thrive in lakes and rivers of a foreign continent. And to assert, in the face of such facts, that the fish was *created* for its former home, and so was found in it, but not for the latter, and so was not found in it, would be merely playing with words.

Among the most interesting facts relating to distribution are those which connect it with geology. As a result of the investigations of Rütimeyer and others in Germany, and of Wallace in England, it may be laid down as fully ascertained: —

1. *That antiquated forms of life are found in abundance only in regions which have long been shut off from communication with the great northern land-masses.*

2. *That in two portions of land or water which were once united, but have become separated, the amount of difference between the animals inhabiting them will bear some proportion to the length of time that has elapsed since their separation.*

3. *That oceanic islands*[1] *(aside from the intro-*

---

cies of humming-bird in a single extinct volcanic crater in South America; for humming-birds frequent certain flowers only, and are not to be found except where these grow.

[1] Those which never have been connected with any continent.

ductions of species which take place by human agency) are stocked only with such animals and plants as could have been transported, either full-grown, or as seeds or eggs, by the waters of the ocean, by the winds, or by birds.

Only a very few illustrations of the laws just stated can here be given; but it is important that the reader should understand that none of the kinds of evidence in favor of evolution loses more by being represented only by scattered instances than does the argument from distribution. Of the first principle above given, Australia, Madagascar, and South America are striking examples. The Australian fauna, for instance, contains few mammals except those of the lowest orders (the montremes[1] and the marsupials[1]); and the absence of the dog, the cat, the deer, and the monkey family, and of the groups of animals allied to these, gives to the fauna of the country such an aspect of antiquity as has not existed in the more northerly continents since the reptilian age. Now, Australia is separated from the nearest mainland by some fifteen hundred miles of sea; Madagascar is cut off from Africa (to which it once belonged) by the great Mozambique Channel,

[1] See Appendix.

two hundred and fifty miles wide, and in some places over nine thousand feet deep; South America is united to North America only by a slender isthmus, and even this was sunk beneath the sea during some part of the age of mammals.

In illustration of the second principle, we may compare the fauna of the British Isles with that of Europe, and the fauna of Madagascar with that of Africa. The comparison is a good one to make; for Madagascar has been separated from Africa since about the close of the age of mammals, while the British Isles have certainly remained part of the European continent till well into the age of man. In regard to the fauna of the British Isles, Wallace says, —

> "All the higher and more perfectly organized animals are, with but few exceptions, identical with those of France and Germany.[1]

In Madagascar, on the other hand, speaking of the mammals, Wallace says, —

> "The character of these animals is very extraordinary, and very different from the assemblage now found in Africa or any other existing continent. Africa is now most prominently characterized by its monkeys, apes, and baboons, by its lions, leopards and hyenas, by its zebras, rhinoceroses, elephants, buffaloes, giraffes, and numerous

[1] Island Life, p. 313.

species of antelopes. But no one of these animals, nor any thing like them, is found in Madagascar; and thus our first impression would be, that it never could have been united with the African continent. But as the tigers, the bears, the tapirs, the deer, and the numerous squirrels of Asia, are equally absent, there seems no probability of its ever having been united with that continent." [1]

In illustration of the third principle, the Sandwich Islands offer themslves as the best example of strictly oceanic islands, situated as they are twenty-three hundred and fifty miles from the nearest mainland (the coast of California), and with the nearest group of islands six hundred or seven hundred miles distant. No land mammal nor amphibian could travel by sea over such vast distances as these, and accordingly no member of either of these great classes of animals is found native in the islands. Their birds, too, largely belong to the orders of waders, swimmers, and birds of prey,—all groups marked by great powers of flight. No other vertebrates are found native, excepting two lizards. Of the remaining animals, the most distinctive are the land-shells already mentioned; and of these there are between three hundred and four hundred known species, *all of them peculiar to the Sandwich Islands.* Vegetation is abundant; but

---

[1] Island Life, p. 381.

more than three-fifths of the plants are confined to these islands, and there is an immensely large proportion of ferns. Among the flowering plants I do not notice one in the list quoted by Wallace which has a heavy, perishable seed (like acorns, most nuts, and so on); while the family which embraces the most species is one[1] whose seeds are frequently carried great distances by the wind.

The ancestors of the numerous snails of these islands may have been very few in number; since the first immigrants to so promising a field would have had an unusually good opportunity to multiply, and in multiplying they may well enough have varied so as at length to produce all the present species. The eggs of these snails were probably first brought to the Sandwich Islands on the feet of birds, in a manner first suggested by Mr. Darwin.

Birds, too, may well have brought many of the seeds of plants, some in their crops, and others clinging to the mud on their feet.

The spores[2] of ferns are as fine as dust, and multitudes of these may have been carried to the islands by the wind. How the lizards of the

---

[1] The Compositæ, or family of compound flowers, like the daisy, aster, thistle, and so on.

[2] Little bodies answering the purpose of seeds.

Sandwich Islands reached their present home is unknown;[1] there are sufficient grounds for believing that these animals are possessed of some as yet undiscovered means of travelling for great distances by water.

What bearing the facts and principles just given have on the development theory may be best shown by stating what laws we should expect to find governing the distribution of animals and plants, if the innumerable species *were the result of acts of creation, in the ordinary sense of the term.* If this were the case, we might reasonably expect: —

1. *That new species of modern forms would appear just as largely in separated lands as in the great connected land-masses.* For, if the new species are supposed to be made in conformity with geological changes in the earth's surface, they should be as frequent in the separated as in the connected lands; since such changes are more frequent, as a rule, in the former than in the latter. Or, if the supposed creations were purposeless, they would be as likely to occur in one place as in another.

2. *Creations (if wisely adjusted to the conditions of animal and of plant life) should in sepa-*

---

[1] Island Life, p. 265.

rated regions take no account of the lapse of time since the separation occurred, but only of the amount of difference in soil, climate, and other circumstances which had come about after the separation.

3. *The inhabitants of oceanic islands should, if specially created in them (as every species peculiar to an island or to a group must have been, according to the special creation theory), be found established where they are best fitted to flourish.* Toads and frogs should be as much more numerous than lizards as they are on mainlands. Mammals, too, where the conditions are as well adapted for them as is often the case (for instance, at Porto Santo), should abound.

It will already have been seen that the above conclusions, *which would be unavoidable if the special creation theory were true*, exactly reverse the known facts in regard to distribution. Is it, then, strange, that, since the death of Professor Agassiz,[1] there has been no celebrated thinker on the subject of distribution who is not also a believer in the theory of descent?

---

[1] In 1873.

CHAPTER IX.

THE ORIGIN AND ANTIQUITY OF MAN.

IN the preceding chapters, while something has been done toward illustrating the way in which animals might gain by improvement or specialization of their physical constitution, there has been no consideration of the advantages that might be derived from a more fully developed brain and the increase of mental power which it would bring. Yet, even were there no evidence for or against such a supposition, who could doubt that a gain in mind might serve species in the struggle for existence not less surely than a gain in body? As we should expect to find the facts in this regard, so they actually present themselves. Pursuing the animal life-history of the earth from the age of Eozoon to the age of man, the student may read the story of the acquisition of a nervous system, then of a brain, and, after that, a continued progress in brain-development.

Or again, if we consider the case of the vertebrate animals by themselves, the same general truth is strikingly exemplified; since the first type to appear, that of the fishes, is lowest in brain-development; while the last type, that of mammals, is the highest in this respect. Even within the class of mammals, the same law holds good, as is most strikingly illustrated by Professor Marsh's comparison of the brain of the Brontotherium (a quadruped of the middle part of the mammalian age) with the brain of a related animal, the modern horse.[1] Now, it is a well-recognized fact, that the most extensive and profitable variations among animals are likely to occur in those organs which are already highly developed, or, in other words, that specialization appears to make the most rapid progress in parts which have before become much specialized. Out of the hundreds of examples that might be quoted in illustration of this, one must suffice. Among pigeons the fantail variety is valued solely for the wide-spread tail. This has varied greatly in size, form, and number of feathers from that of the wild parent species. And it is among fan-tails that we still meet with more differences in the development

---

[1] Dana's Manual of Geology, p. 508.

of the tail in individual birds than can be found in any other variety of pigeon.

Following up the history of brain-development as recorded in the fossils of vertebrate animals, from the fishes of the silurian to the mammals of the mesozoic, the decided superiority of the mammalian brain is manifest enough.

Evidently there was no previous group with brain enough to outstrip other animals in the struggle for existence, solely by reason of its superior mental powers. Scaly coats of mail, formidable teeth, or tremendous muscular power, had characterized some of the vertebrates from the beginning; while many of the great swimming saurians of the reptilian age added exceeding swiftness to their other qualifications for attack or defence. But it was not until mammals appeared, that intelligence became so important a factor in the struggle for existence that we might naturally expect as a result rapid and unusual variations in brain-development. We must keep constantly in mind the principle already stated, that the most variation is found occurring in those parts which are already highly specialized.

Man, as Professor Cope has well argued, though the highest of animals, and therefore of mammals, is not the highest *as a mammal* in any

other respect save that of possessing a superior brain.

"In all general points his limbs are those of the primitive type so common in the eocene.[1] He is plantigrade,[2] has five toes, separate carpals[3] and tarsals,[4] short heel, rather flat astragalus,[5] and neither hoofs nor claws, but something between the two: the bones of the fore-arm and leg are not so unequal as in the higher types, and remain entirely distinct from each other, and the ankle-joint is not so perfect as in many of them. In his teeth his character is thoroughly primitive. . . . His structural superiority consists solely in the complexity and size of his brain. . . . A very important lesson is derived from these and kindred facts. The monkeys were anticipated in the greater fields of the world's activity by more powerful rivals. The ancestors of the ungulates[6] held the fields and the swamps; and the carnivora, driven by hunger, learned the arts and cruelties of the chase. The weaker ancestors of the Quadrumana possessed neither speed, nor weapons of offence and defence; and nothing but an arboreal life was left them, where they developed the prehensile powers of the feet. Their digestive system unspecialized, their food various, their life the price of ceaseless vigilance, no wonder that that inquisitiveness and wakefulness was stimulated and developed which is the condition of progressive intelligence."[7]

[1] The first period of the tertiary age.

[2] In the habit of walking flat on the sole of the foot.

[3] Wrist-bones.

[4] Heel-bones.

[5] The largest ankle-bone.

[6] Hoofed animals.

[7] Professor Edward D. Cope, The Relation of Man to the Tertiary Mammalia, pp. 884, 885.

In order to gain a clear conception of the zoölogical relations of man, let us recapitulate the life-history of the individual man from the beginning.

We shall find the future human being a mere nucleated cell, a little speck of albuminous jelly already described (in Chap. VI.) as the mammalian egg. So closely do the form, the size, and the structure of this little cell remind us of the amœba-cell, that Haeckel's inference is most natural: —

> "The ancestors of the higher animals must be regarded as one-celled beings, similar to the amœbæ which at the present day occur in our rivers, pools, and lakes. The incontrovertible fact, that each human individual develops from an egg, which, in common with those of all animals, is a simple cell, most clearly proves that the most remote ancestors of man were primordial[1] animals of this sort, of a form equivalent to a simple cell. When, therefore, the theory of the animal descent of man is condemned as a 'horrible, shocking, and immoral' doctrine, the unalterable fact, which can be proved at any moment under the microscope, that the human egg is a simple cell which is in no way different to those of other mammals, must equally be pronounced 'horrible, shocking, and immoral.'"

Nor is this resemblance to the lower animals confined to the egg-stage of the human being;

[1] Belonging to one of the first geological periods.

for, after the development of the ovum is fairly under way, there are some weeks in the life of the human embryo during which no more could be decided, from the closest study of it, than that it was (like the embryo described by Von Baer, as quoted in Chap. VI.) that of some animal with a backbone. At a later period of embryonic life, we shall find that the human embryo has taken on a form peculiar to mammals, and that this form soon becomes as strikingly like the embryo of an ape as either is now different from that of any other mammal.

The human infant, also, has some very apelike characters; such as the narrow hips, the soles of the feet brought toward each other by the incurving thighs, the protuberant abdomen, the disproportionate length of the arms, the shortness of the hair on the head, and the general distribution of hair over the body, and the lack of a bridge to the nose. On the other hand, the young ape has a far more human or less brutish look than the adult, from the fact that the huge projecting jaws and teeth, such as appear in the adult gorilla for example, are only attained at a rather mature age. So it is, too, with the great, bony ridges on the skull of this ape. Now, the tendency of such embryonic and infantile resemblances as have just

Fig. 25. — Adult Male Orang.

been alluded to — special resemblances between man and apes, since they are shared with no other mammals — is to lead us to infer, that, if we are related to any of the lower animals, we are most closely related to the apes. And, if they and we are descended from a common ancestry, we should expect to find the likeness between the human being and the ape closest in the embryonic stage of existence, and growing less towards maturity, as is really the case. But how closely similar is the human body and the body of one of the higher apes? How great an *external* resemblance there is, the preceding figure of one of the most manlike apes will show better than words. How great is the similarity in *structure*, let Professor Huxley answer.

After a full account of the characteristics and habits of the gorilla, chimpanzee, orang, and gibbons, followed by a minute anatomical comparison of these animals with each other, with lower members of the order, and with man, he says, —

"Whatever part of the animal fabric, whatever series of muscles, whatever viscera,[1] might be selected for comparison, the result would be the same, — the lower apes and the gorilla would differ more than the gorilla and the man."[2]

---

[1] Contents of the great cavities of the body.

[2] Man's place in Nature, p. 101.

But it is often urged that man is the only animal that has two hands and two feet, and that in this respect there is a vast gap between the highest ape and man. To this Professor Huxley answers, that the foot of man differs from his hand mainly: —

1. By the different arrangement of the ankle-bones from the wrist-bones.

2. By the possession of two short muscles in the foot, — one in the under, and the other in the upper part of it, — which serve respectively to bend and to straighten the toes.

3. By the possession of a muscle (the *peronæus longus*) which is attached to the outer leg-bone, and whose cord or tendon passes over the outer part of the ankle, and then obliquely across the foot, to its attachment at the base of the great toe. Neither the two short muscles found in the foot, nor the *peronæus longus*, nor any thing like either of them, is to be found in the human hand and arm.[1] Now, "Every monkey and lemur exhibits the characteristic arrangement of tarsal [ankle] bones, possesses a short flexor [bending] and extensor [straightening] muscle, and a *peronæus longus*."[2]

The old epithet *four-handed*, as applied to

---

[1] Huxley, Man's Place in Nature, p. 107. [2] Ibid., p. 112.

apes and other members of the order primates, is then incorrect; and there is in this respect no essential difference between apes and man. Much has been said by opponents of the doctrine of the common descent of man and the lower animals in regard to the differences between the brains of men and of apes. But Professor Huxley, after reviewing and comparing their brain-characteristics, goes on to say, —

> "So far as cerebral [brain] structure goes, therefore, it is clear that man differs less from the chimpanzee or the orang than these do even from the monkeys, and that the difference between the brains of the chimpanzee and of man is almost insignificant when compared with that between a chimpanzee brain and that of a lemur." [1]

The same thing is true of the differences in *size* of brain. The largest human skull on record (that of a woman) had a capacity of one hundred and fifteen cubic inches; the smallest brain of an adult with sound mind measured sixty-two cubic inches; while the brain of the gorilla has been found to measure thirty-four and a half. There is, then, more difference in bulk between the largest and the smallest healthy human brain than between the latter and that of

---

[1] Man's Place in Nature, p. 120.

the gorilla. And again: in regard to the bulk of the brain Huxley says, "The lowest apes differ as much, in proportion, from the highest as the latter does from man." Yet, in making this statement so positively, Professor Huxley does not, nor does any capable judge of the matter, deny the existence of an extremely large number of details in which man is anatomically different from the ape. From a multitude of such details of structure, any good comparative anatomist could distinguish the skeleton of a man from that of any other animal in the order primates. In the muscles, too, and in many other parts, there are plenty of slight differences between even the highest apes and man.[1]

But it is often claimed that the gap between the mental powers of man and of the most intelligent of the animals below him is too great ever to have been bridged over by natural causes, and that, even if the descent of man's *physical* nature from a common ancestry with that of the

---

[1] Yet Professor Owen, one of the strongest opponents of the theory of the common descent of man and apes, says,—

"I cannot shut my eyes to the significance of that all-pervading similitude of structure,—every tooth, every bone strictly homologous [corresponding],—which makes the determination of the difference between Homo [man] and Pithecus [ape] the anatomist's difficulty."—*Journal of the Linnæan Society*, London, 1857.

apes were to be admitted, we must still suppose the human mind to have been derived from some other source and in some supernatural way. It has, however, been shown by Darwin, in his "Descent of Man," by Herbert Spencer, in his "Biology," "Sociology," "Psychology," and "Ethics," as well as by the writings of Edward D. Cope and Chauncey Wright, that most, if not all, the mental and moral faculties of man may have been developed in a purely natural way.

Without the able explanations of the authors just quoted, however, it might readily be imagined that the apparent difficulty would prove susceptible of some natural solution; since the mental interval between man and apes is no greater than that between members of the same great groups in other divisions of the animal kingdom. No chasm, for instance, could well be wider than that between the ants and certain other insects, as the scale-insects[1] and the twisted-wings.[1]

Ants have been found to possess a very acute

[1] Scale-insects are very abundant on bark, leaves, and some kind of fruit: they may commonly be found on the bark of apple-trees, appearing as little circular, close-clinging scales. The twisted-wings get their name from the fact of their wings being twisted in the mature insect: in the immature form, the animal is a parasitic grub.

touch, a keen sense of smell, and fair eyesight (at short distances). They are able to converse with each other by means of their antennæ, or feelers, in such a way as to give and receive intelligence very quickly and accurately. They build houses, roads, and tunnels, make gardens, hold slaves, and even keep plant-lice (much in the same way as men keep cows), and milk and feed and take care of these domesticated insects. Says Professor Macalister, —

> "In intelligence and in interest they [ants] may be looked on as bearing to the other invertebrates something of the same relation which man has to his neighboring vertebrates."[1]

On the other hand, the full-grown scale-insect consists simply of a roundish scale hollowed out somewhat on the under side, destitute of feet, and clinging motionless to the leaf, bark, or fruit of the plant on which it feeds. The female of the twisted-wings is maggot-like in shape, and passes her existence in a motionless condition, embedded in the body of a wasp.

If the two insects just described can be properly ranked in the same class with ants, there is certainly no difficulty in ranking man, even

---

[1] Zoölogy, Invertebrata, p. 135.

in view of his intellectual and moral nature, among mammals; and, if a naturalist does not reject the theory of descent in the former case, he certainly need not do so in the latter.

It would hardly be fitting in any summary, however brief, of the facts which tend to prove man's community of origin with the apes, to omit some notice of the fact that idiots not infrequently present striking instances of reversion to what may fairly be taken to have been the characteristics of an ape-like ancestry. A low, retreating forehead, projecting jaw, prominent canine teeth, and slender, claw-like fingers are some of the physical traits of certain idiots. Along with these features, and probably as a consequence of the small (and ape-like) brain, one sometimes finds the uncontrolled curiosity, the continual movements, the incessant chattering and screaming which we are accustomed to associate with monkeys.

For many curious and important bodily and mental traits, in which man appears to display his community of origin with the lower animals, the reader must consult such works as Darwin's "Descent of Man," or Haeckel's "Evolution of Man." Lack of space makes it necessary in this half-chapter to stop short with a general statement of the nature of the known facts

which bear on the *origin* of the human race, and a few of the conclusions which have been drawn from them. Even a concise summary of the principal facts to be considered would fill a large volume. One common objection must be answered before the subject is dropped. It is often urged that man is physically, mentally, and morally too perfect a being to have sprung from any ancestor akin to the lower animals. To this objection it may be answered, that physically man is far enough, at best, from being a perfect animal, while mentally and morally the most savage races (which may properly be reckoned most similar to man as he at first appeared) are lower in the scale of being than any one who has not known such races can well imagine. Of man's physical defects, the injurious, degenerated organs, such as the vermiform appendage and the coccyx already mentioned, are good examples. Other imperfections, too, there are in great number. To cite only one: man (in common probably with all other vertebrate animals) possesses an organ of vision in which the highest living authority has pointed out no less than six decided optical defects.[1]

---

[1] Helmholtz, Popular Lectures on Scientific Subjects, vol. i. pp. 215–224.

So serious are these, that no competent manufacturer of optical instruments would allow any imperfection of the sort to remain in any piece of work on which his reputation at all depended. Of course it is not meant to imply that the products of human handiwork, such as the microscope, are nearly as wonderful as is the human eye. No words can do justice to the marvellous structure and working of the eye; but, for all that, it is far enough from *perfect.*

How utterly beast-like in mental and moral regards the lowest races of men are, may be shown by a few extracts from Lubbock's "Origin of Civilization, pp. 5, 6."

"Speaking of the wild men of Borneo, Mr. Dalton says that they are found living 'absolutely in a state of nature, who neither cultivate the ground nor live in huts, who neither eat rice nor salt, and who do not associate with each other, but rove about some woods like wild beasts. The sexes meet in the jungle, or the man carries away a woman from some campong. When the children are old enough to shift for themselves, they usually separate, neither one thinking of the other. At night they sleep under some large tree, the branches of which hang low. On these they fasten the children in a kind of swing. Around the tree they make a fire to keep off the wild beasts and snakes. They cover themselves with a piece of bark, and in this also they wrap their children: it is soft and warm, but will not keep out the rain. The poor

creatures are looked on and treated by the other Dyaks as wild beasts.' "[1]

Take the following description of a Bushman, quoted from Lichtenstein: —

"The man had the true physiognomy of the small blue ape of Caffraria. What gives the more verity to such a comparison was the vivacity of his eyes and the flexibility of his eyebrows, which he worked up and down with every change of countenance. Even his nostrils and the corners of his mouth, nay, his very ears, moved involuntarily, expressing his hasty transitions from eager desire to watchful distrust. There was not, on the contrary, a single feature in his countenance that evinced a consciousness of mental powers, or any thing that denoted emotions of mind of a milder species than what belong to man in his mere animal nature."[2]

Lubbock goes on to say, —

"Mr. Dove, speaking of the Tasmanians, asserts that they were entirely without any 'moral views and impressions.' "

And again: —

"'Conscience,' says Burton, does not exist in Eastern

---

[1] In a recent account of his travels in Borneo, Carl Bock describes a visit to a village of the Orang Poonans, or forest-people above mentioned. From the observations made during his afternoon's visit, Mr. Bock draws much the same conclusions in regard to the condition and habits of this singular people as those which I have quoted.

[2] Origin of Civilization, Lubbock, p. 6.

Africa, and 'repentance' expresses regret for missed opportunities of mortal crime."

Further on Lubbock says, —

"It is very clear that religion, except in very advanced races, has no moral aspect or influence. The deities are almost invariably evil." [1]

And if we turn to the consideration of the social life, or rather lack of it, among savages, we shall find the picture so hideous, that one turns from it with a shudder of disgust.

Among the most animalistic races, brute force takes the place of law, lying is honored, stealing is applauded, open war and secret murder are the favorite pursuits. There is no marriage, and there are therefore no homes; relatives are unknown; and modesty in either sex is a thing unheard of. In short, the most inhuman monster of crime that ever was condemned by a court, and executed by an officer of the law, would, among such tribes as those of the Australian natives, surely pass for the embodiment of all excellences, and rise to an uncontested chieftainship. Yet out of such elements, and from the midst of such degradation, scientists must conclude that the human race as it now is

[1] Origin of Civilization, p. 266.

has risen. And surely it is better so than that the race should have fallen (as all students of mankind once believed it did, and as some still believe) from a comparatively perfect state. What better earnest could there be for the triumphant future of humanity than the fact of its having ascended from the condition of the lower animals?

There still remains for discussion in this chapter the question how far the fossil remains of prehistoric man throw light upon his early condition or his probable antiquity. On this subject alone, many extended works have been written; but here there can only be given a few conclusions, without any effort to quote much of the evidence.[1]

History can tell nothing in regard to the earliest men; for the oldest historical records as yet discovered go back not quite seven thousand years, and then show us a race (in Egypt) already far along in civilization.

Geology reveals much earlier chapters of the life of the race, inscribed in the rocks; but it is necessary, before considering these conclusions, to describe in a few words the condition

---

[1] Two of the most compact and readable books which give a summary of the evidence are Rau's Early Man in Europe, and Lubbock's Prehistoric Times.

of things on the earth's surface during the tertiary and the quaternary age.[1]

During tertiary time the general climate of the earth was apparently more equable than at present, and it is certain that a temperate climate prevailed in such extreme northern lands as Greenland and Spitzbergen. Throughout a large portion of the age the latter country, which is now covered with almost perpetual snow and ice, supported vigorous forests of hazels, poplars, alders, beeches, and sycamores, where now only dwarf arctic willows and a few other small plants constitute the entire flora.[2] Mammals, some of them of great size, and strikingly different from those of the present day, were extremely abundant over all the great continents, and immense whale-like forms peopled the seas. During part of the age, Europe was an archipelago, only the highest lands being out of water; while at a later period the Euro-Asiatic continent was uplifted over great regions; and it is back to this time that the principal mountains of Europe and Asia, from the Pyrenees to the Himalayas, date.

At the beginning of the quaternary age the

---

[1] The tertiary age was the one just preceding ours, and the the quaternary is the age in which we live.

[2] Dana's Manual of Geology, p. 515.

northern continents seem to have been elevated far above their present levels.

The European continent extended so far out beyond its present limits as to include the British Islands as part of the mainland, they being united on the east with Denmark, and on the west with a great portion of land, now buried beneath the sea, far to the west of Ireland, and reaching south to the Bay of Biscay. Accompanying the elevation of the northern lands there was ushered in, at the beginning of the quaternary age, the greatest period of ice-action of which geology has preserved a record, — the glacial period. In North America a series of great glaciers radiated from the highlands south of Hudson's Bay, and covered the north-eastern part of the continent as far south as the Ohio River, and away westward to the Rocky Mountains.

In Europe similar glaciers stretched from the mountains of Scandinavia, and from other elevated centres, toward the south, and buried most of Northern Europe beneath mountains of ice. How the mighty "ice-foot" of one of these immense glaciers must have looked as it entered the sea, perhaps far to the west of the present situation of the British Isles, can best be understood from a look at the accompanying illustra-

tion, which represents the great Greenland glacier of to-day at its entrance into the sea.

Following the glacial period, there seems to have been an interval of subsidence, called the "mammoth period," from the abundance in Europe, at that time, of the hairy elephant, or mammoth. This period was accompanied by the return of a mild climate and the melting of the glaciers; but (in Europe) the glaciers once more came back for a time, finally disappearing, to be succeeded by the climate of the present.[1] How many centuries each of the periods above outlined included, no one is as yet able to say, although many attempts have been made to solve the problem. From the fact that the water at Niagara Falls has cut a channel back six miles through the rock toward Lake Ontario since the mammoth period, the time that has elapsed since its close has been variously calculated at from thirty-one thousand to three hundred and eighty thousand years.[2] From a careful study of the astronomical causes to which the glacial period, in his opinion, was due, Mr. Croll puts the date at which it began about two hundred and

---

[1] Geologists are not entirely agreed as to the succession of events *after* the first glacial period.

[2] Dana's Manual of Geology; pp. 590, 591.

FIG. 26.—Greenland Glacier.

forty thousand years ago.[1] From the amount of filling-up that has taken place in Lake Geneva, Monsieur Forel calculates that it is a hundred thousand years since the retreat of the glaciers in that region.[2]

It is evident how greatly the results of different investigators disagree in regard to the date of any given event in the present geological age; but it is also plain, that, if man has occupied the earth only during this our so-called age of man, he has existed during an exceedingly long time.[3]

It is on all hands admitted that man has existed during the whole of the present geological age.

From the beds of Swiss lakes, from the shell-mounds and peat-mosses of Denmark, from the caves of all Western Europe, from the gravels of ancient river-beds in the same region, the remains of successively older and older prehistoric races have been collected. Many of the most important questions in regard to the antiquity and early condition of the race are still under discussion; but this much is certain, that the

1 Climate and Time, pp. 325–328.

2 Quoted by Quatrefages, The Human Species, p. 138.

3 It may be added, that geologists generally favor some of the larger figures given for the periods above mentioned.

earliest races not only were less expert in the arts, but also had a less perfect physical organization, and were more animalistic in their make-up, than the later races. The great multitude of the earliest remains of man of the present geological age are found in the river-gravels or river-drift. It is a fact well known to geologists that rivers often flow at present in beds far lower than those which they originally occupied, and that the remains of their former banks and beds may in such cases often be found at an elevation of many feet on either side of them. The most wonderful example of these river-terraces, as they are named, in our own country (and, for that matter, in the world), are found along the Connecticut River and some of its tributaries. From three to five or more terraces may, in places, be counted, the uppermost sometimes much more than a hundred feet above the present banks. In the accompanying figure is represented the succession of terraces as they appear in France along the River Somme.

The highest bank, is of course, the oldest; but even in these highest layers of gravel, along the banks of European rivers there have been found evidences of human handiwork, in the shape of the roughest kind of flint-flakes, such as might be used for arrow-heads, spear-heads, knives, or scrapers.

In England along the Thames, and in France along the Somme, such finds have been particularly abundant: and it was the discovery of implements at Menchecourt, near Abbeville, in the latter valley, by Boucher de Perthes, a persistent French archæologist, that first called the attention of the scientific world to what is now known as the river-drift man. One of the St. Acheul implements is represented by Fig. 28.

In Fig. 29 is given a section of the gravel-pit

FIG. 27. — Terraces of the Somme.

1. Peat, twenty to thirty feet thick, resting on gravel, *a*.
2. Lower level gravel, with elephants' bones and flint tools, covered with loam deposited by the river, twenty to forty feet thick.
3. Upper level gravel, with overlying loam and with similar fossils, in all thirty feet thick.
4. Upland loam, without shells, five or six feet thick.
5. Early tertiary strata, resting on the chalk in patches.

from which these implements were taken, and it is easy to gather from the diagram that they are as old as the remains of prehistoric animals found alongside of them.

Amid what surroundings the river-drift man lived in England, with the Thames flowing seventy feet above its present channel, and with Great Britain, not, as now, an island, but part of a great extension of the continent of Europe,

let Mr. Dawkins, one of the foremost English authorities on prehistoric man, tell: —

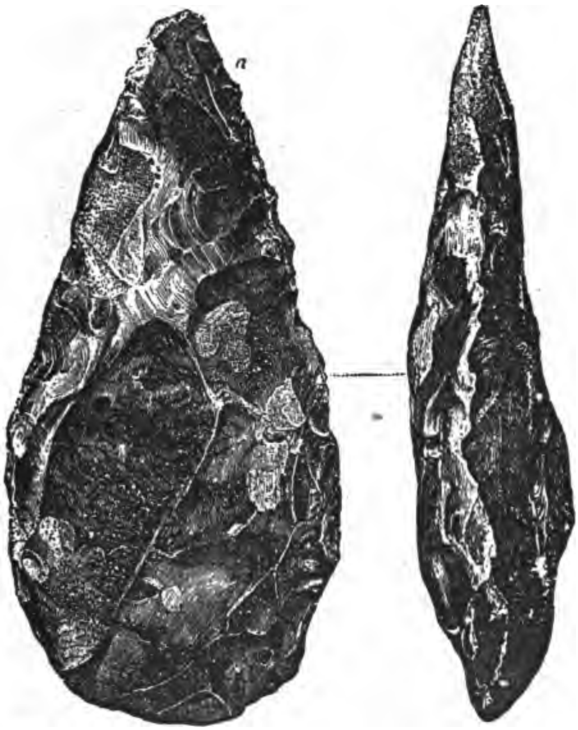


FIG. 28. — Flint Implement, St. Acheul.
a. Side-view. *b*. Same, seen edgewise.

"The district [valley of the Thames] was then haunted by many extinct wild animals and by living species no

longer found together in any part of the world. Stags and roe-deer lived in the forest, side by side with the gigantic and extinct Irish elk, the woolly-haired rhinoceros, and the straight-tusked elephant. Three kinds of rhinoceros, one of them covered with wool and hair, fed on

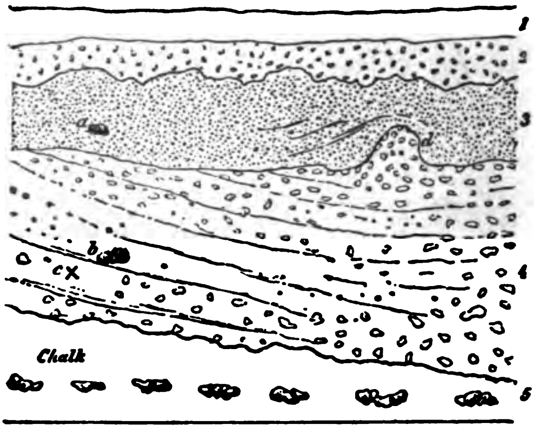


FIG. 29. — Section of Gravel-Pit, St. Acheul.

1. Vegetable soil and made ground, two to three feet thick.
2. Brown loam, angular flints, and gravel, three feet thick.
3. White sand, marl, and fragments of chalk, nine feet thick.
4. Flint-gravel and chalky sand, flints somewhat angular, somewhat stratified; bones of mammals; grinder of elephant at *b;* and flint implement at *c*, — ten to fourteen feet.
5. Chalk with flints.

a. Part of elephant's molar tooth, eleven feet from surface.
b. Entire molar tooth of a fossil elephant, seventeen feet from surface.
c. Position of flint hatchet, eighteen feet from surface.

the branches and the undergrowth; wild boars ploughed up the ground in search of food; and the glades afforded pasture to innumerable horses, bisons, and large horned

uri;[1] and, when forest and glade were alike covered with a snowy mantle, a few musk-sheep,[2] now the most arctic of all the herbivores, were to be seen on the banks of the Thames in Kent. . . .

"The stillness of the night was from time to time broken by the weird laughter of the spotted hyena and by the roar that proclaimed the presence of the king of beasts. Otters pursued their finny prey in the Thames at Gray's Thurrock; and at Ilford beavers were to be seen disporting themselves round their wonderful habitations, and vanishing beneath the surface, as if by magic, at the splash caused by the bulky form of the hippopotamus as he plunged into the water. . . . The central figure, however, in the picture is proved by recent discoveries to have been man. Not only have flint implements of the ordinary river-drift type been obtained from the brick-earths of Crayford, along with remains of the animals above mentioned, but Mr. Flaxman Spurrell has been able to fix the place where the hunter sat on the ancient bank of the Thames, and fashioned the blocks of flint to his various needs. . . . And could we penetrate to the banks of the streams, guided by a thin column of smoke rising above the tops of the trees at Hackney or Gray's Inn, we should come upon the rude shelters of the river-drift hunters — the men selecting blocks of flint, and chipping implements out of them; the women preparing the meal of flesh; and the children looking on, and breaking the silence of evening with their shouts — on

---

[1] A kind of large ox which lived in Europe as late as the time of Julius Cæsar.

[2] Musk-ox is the more usual name. James Geikie and some other geologists do not believe that the musk-ox and the lion lived in Great Britain *at the same time*.

those very spots where now is to be heard day and night the voice of our great city."[1]

But did men exist at a period even earlier than the river-drift? Did man first appear at some time during the age of mammals?

This question can only be answered within the limits of the present chapter by giving conclusions, without going into details as regards the evidence from which those conclusions are drawn. Mr. Dawkins does not admit that there is evidence of the existence of men earlier than the river-drift, but would rather suppose that chipped flint implements, which undoubtedly date back to the mammalian age, are the work of some one of the higher apes, than that they were fashioned by the hand of man.

On the other hand, the Abbé Bourgeois, Dr. Hamy, and M. de Quatrefages, Worsaae, Capellini, Delaunay, Ribeiro, M. de Mortillet, Professor Huxley, James Geikie, and Lubbock find the evidence sufficient to warrant the belief that man originated during the tertiary age, perhaps at its very beginning.

How widely man has ranged over the earth's surface during prehistoric times may be even

---

[1] W. Boyd Dawkins's article, "The British Lion," reprinted in the Popular Science Monthly, November, 1882.

further demonstrated by future researches; but it is already clear that he occupied, in glacial and post-glacial times, not only Europe, including the British Isles and the islands of the Mediterranean, but also Egypt and North and South America. The number and some of the distinctive characteristics of the later prehistoric races of Europe have been pretty clearly made out. In tabular form the classification of Quatrefages and Hamy would be as follows:—

DIVISION I. Long-headed Races.	1. Canstadt race. 2. Cro-Magnon race.
DIVISION II. Short-headed Races.	3., 4. Races of Furfooz. 5. Race of Grenelle. 6. Race of La Truchère.

By long-headed races those are meant in which the distance from front to back of the skull is comparatively great; while in short-headed races this dimension bears a much less proportion to the distance from side to side of the head. The Australian natives have heads of the former type; the Cossacks, of the latter. Names have been assigned to the races, as above classified, from European localities where their remains have been obtained. According to the authors of this classification, these races all

lived subsequent to the age of mammals,[1] in the order given; the Canstadt race being the oldest. Of the characteristics of the later races there is no need here to speak.

The Canstadt race, however, takes us so much farther back toward the origin of the human species, that a few words in regard to it may well be given. Even the most thorough-going opponents of the theory of descent are forced to admit, with Quatrefages, that there is an immense step downwards from later human races to this early one. Professor Huxley, on seeing a cast of the Neanderthal skull,[2] at once pronounced it to be the most ape-like he had ever beheld.

Says the distinguished anthropologist, Professor Schaafhausen, of this skull, —

> "No other human skull presents so utterly bestial a type as the Neanderthal fragment. If one cuts a female gorilla skull in the same fashion, the resemblance is truly astonishing, and we may say that the only human feature in the skull is its size."[3]

---

[1] Nothing exact is known in regard to the characteristics of the men of the mammalian age, since only a few implements have as yet been found to represent them.

[2] A famous skull of this type found near Düsseldorf, Prussia.

[3] Quoted by Professor Grant Allen, in an article in the Popular Science Monthly, November, 1882.

Fig. 30. — The Neanderthal Skull.

A. Side View. B. Front View. C. Top View.

The following diagram serves well to illustrate the general outline of the Neanderthal skull, and the fact that its form is intermediate between the ape on the one hand and the higher human races on the other. Speaking of the

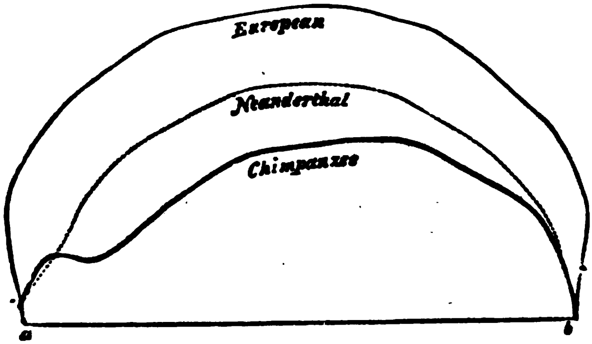


FIG. 31. — Comparative Section of Three Skulls.
a. Front. *b*. Back.

unusually large cavity which separates the two layers of bone in the skull, just above the eyes, thus causing the outer layer to project enormously, Professor Rolleston, an able English anatomist, "assures us, that, if these frontal sinuses had been found without the skull to which they are attached, he would have been a bold man indeed who would venture to pronounce them human."[1]

[1] Quoted by Allen, Popular Science Monthly, November, 1882.

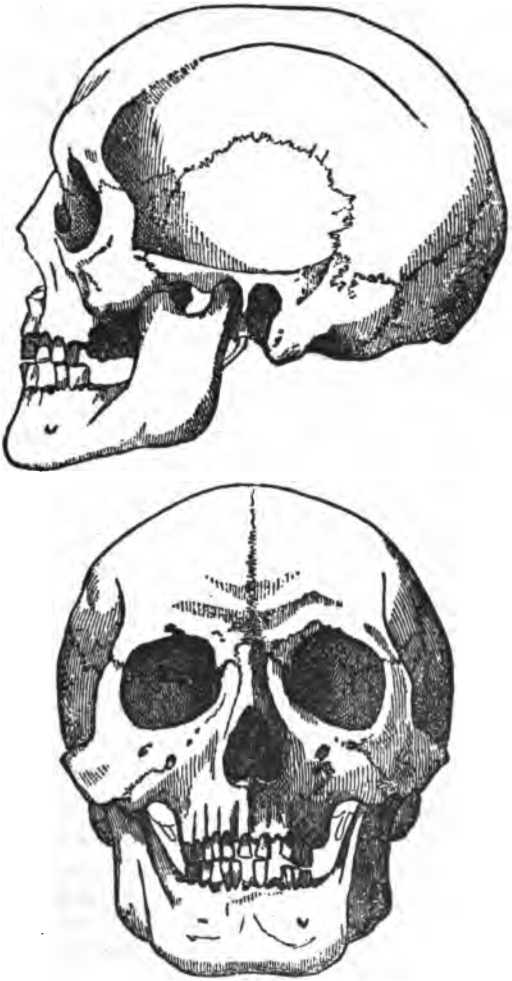


FIG. 32. — Skull of Modern European.

A mere comparison of the views in Fig. 30 with the skull in Fig. 32 will suffice to show the vast progress of the race from the former to the latter type.

Not less brutish than the Neanderthal skull is another fragment, representing apparently the same Canstadt race; namely, the celebrated jaw of La Naulette.[1] This remarkable jaw, with its huge projecting canines, is certainly ape-like in the extreme.[2]

The Canstadt man, with his animalistic, barrel-like chest, stout, misshapen limbs, with his startlingly flattened head, forehead jutting far out just above the eyes, and the eye-sockets bulging so widely at the side of the head as to be visible even from behind, and with gorilla-like eye-teeth, must have presented an appearance in the highest degree hideous and ferocious. But, if this was the appearance of the Canstadt man, what must we imagine to have been the appearance of those earliest men, or man-like animals, the makers of flint implements of the mammalian age?

Here *facts* are lacking, and all that can be

---

[1] Found in a cave, the Trou de la Naulette, in Belgium.

[2] So also, it would seem, is another jaw, found in the Schipka cave, Moravia; but, as its exact character is in dispute, it need not be here described.

said is *conjectural.* Yet a scientific conjecture is far better than no thought on a subject; for, as Lord Bacon has well said, "truth emerges sooner from mistake than from confusion." Says Professor Allen in the article so frequently quoted, —

"We may not unjustifiably picture him to ourselves as a tall and hairy creature, more or less erect, but with a slouching gait, black-faced and whiskered, with prominent prognathous [projecting] muzzle, and large, pointed canine teeth, those of each jaw fitting into an interspace in the opposite row. These teeth, as Mr. Darwin suggests, were used in the combats of the males. His forehead was no doubt low and retreating, with bony bosses [knobs] underlying the shaggy eyebrows, which gave him a fierce expression, something like that of the gorilla. But already, in all likelihood, he had learned to walk habitually erect, and had begun to develop a human pelvis [hips], as well as to carry his head more straight upon his shoulders. That some such an animal must then have existed seems to me an inevitable corollary [consequence] from the general principles of evolution, and a natural inference from the analogy of other living genera. Moreover, we actually find rude works of art which occupy a position just midway between the undressed stone nut-cracker of the ape, and the chipped weapons of palæolithic[1] times. This creature, then, if he existed at all, was the real primitive man, and to apply that term to the cave-men or the

[1] Belonging to the early stone age, before the art of polishing flint implements was invented. The St. Acheul implements are early palæolithic.

drift-men is almost as absurd as to apply it to the civilized neolithic herdsmen."[1]

Of the existence of what one might call ante-prehistoric men, many are no less certain than if their bones had been discovered; for, as Sir John Lubbock has well said, the question is not whether these men had bones, but whether they actually existed; and that they did exist is amply proved by the rude flakes of flint which they left, as well as by the bones of animals on which the impressions of those flint knives still remain. Yet there are chances that more light may some time be thrown on this difficult subject; for, says Lyell, in closing his great work, "The Antiquity of Man,"—

"We have not yet searched those pages of the great book of Nature in which alone we have any right to expect to find records of the missing links alluded to: the countries of the anthropomorphous [man-like] apes are the tropical regions of Africa, and the Islands of Borneo and Sumatra, — lands which may be said to be quite unknown in reference to their pliocene[2] and post-pliocene mammalia."

A simple diagram will serve far better than any words to illustrate the enormous lapse of

---

[1] Men who lived just before the historic period, in a time when implements were largely made of polished stone.

[2] Belonging to the latter part of the tertiary age.

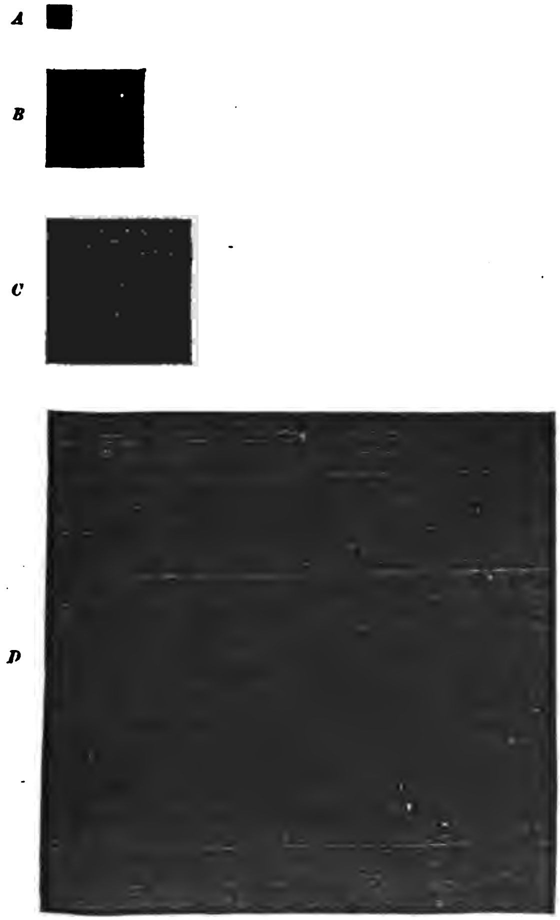


DIAGRAM TO ILLUSTRATE THE POSSIBLE ANTIQUITY OF MAN.

A. The time from the earliest historical period to the present.
B. Time since the close of the last glacial period.
C. Time since the beginning of the next to the last glacial period.
D. Time since the beginning of the tertiary.

time that separates us from the days of primitive man.

So long as many even who are opposed to the development theory find reason to admit that man may have originated *over two and a half million years* earlier than the earliest human bones that have yet been identified, we may well believe that the human race has endured long enough for all the development needed to bring some ape-like animal up to the level of the Canstadt race.[1]

---

[1] The estimate of over two and a half million years, though large, is by no means beyond the figures of the best authorities. Many high authorities are, as already stated, disposed to believe in the existence of the race far back into the tertiary. Croll's estimate, before quoted, is two hundred and forty thousand years for the quaternary age; and Dana makes the tertiary and quaternary together something like three million years. The difference, 2,760,000 years, would stand for the period of development from the time of primitive man to that of the man of the river-drift. Of course no one pretends that such figures as these do any thing more than give us some idea of the relative proportions of the several periods.

CHAPTER X.

HISTORICAL SKETCH.—CONCLUSIONS.

THE complete history of the growth of the development theory would in itself afford a wonderful illustration of a process of evolution.

Whatever be one's knowledge of botany or zoölogy, whatever be one's bias regarding the application of the theory, one cannot fail to see that the thought of to-day is permeated by the one idea of growth, progress, evolution. That thought rules our pursuit of knowledge in all directions, physical, philosophical, ethical.

From the works of Aristotle down to those of the scientists and philosophers of to-day, we find here and there thoughts, suppositions, and conclusions tending towards such an explanation of the organic world as has only been formulated into a working hypothesis since the patient accumulation of facts bearing on the subject was begun by Mr. Darwin, almost half

a century ago. In this place there will only be room for allusion to a very few of the more important steps that have been taken in advancing the theory to its present comprehensiveness.

Herbert Spencer has laid down as a general principle, that the early beliefs of mankind are not usually true beliefs. This is but one special application of the truth, now generally recognized by students of the human race, that man has arisen from an extremely rude and unintelligent condition to the position which he now occupies. The ideas of a savage are no less inferior to our own than are his manners or his morals. And, even long after the savage condition has been left behind, men's conceptions of the laws of nature remain exceedingly imperfect.

Until the eighth century it was universally believed that all substances consisted of earth, air, fire, and water united in various proportions. The circulation of the blood seems to have been merely guessed at, until it was definitely announced by Harvey in 1619; and, up to that time, physiologists in general contentedly acquiesced in the opinion of the ancients, that the blood remains stagnant, or nearly so, throughout the veins. For a long time the arteries were thought to be filled with air. Our

word "artery" comes from a Greek noun meaning *either* windpipe or artery.

Till about three hundred and fifty years ago, the sun, planets, and stars were thought, even by astronomers, to be set in hollow, crystal spheres, which revolve about the earth.

It is only within the present century that the various forces of nature have been recognized as interchangeable modes of motion, convertible one into the other. Heat, light, and electricity, instead of being (as at present) known as so many modes of motion, were long considered to be *substances*, the presence or absence of which in any object made it hot or cold, light-giving or dark, electrified or not. But this misinterpretation of nature did not always proceed from any lack of reasoning power in the scientists of the previous century and of earlier times. There have been few greater thinkers on natural and physical science than Aristotle,[1] and yet any intelligent high-school pupil of our time may understand a multitude of laws of which the great Greek philosopher was ignorant, only because, in his day, the facts from which the laws have been inferred were still unknown. Coming late as it does, the statement of the

---

[1] Died 381 B.C.

development theory in its present form has been able to take into account a vast array of carefully observed facts, the existence of which the naturalist of two generations ago could not have foreseen.

As late as the beginning of the present century there was not enough known of the facts of embryology, zoölogy, botany, paleontology, and geographical distribution, to enable any naturalist, of however penetrating a mind, to form an adequate conception of the processes by which species have come into being. And yet there were not lacking naturalists who saw far enough into the influence exerted upon animals and plants by their surroundings to attribute to this influence as a cause the existence of many, if not all, species. Says Darwin, —

> "It is rather a singular instance of the manner in which similar views arise at about the same time, that Goethe in Germany, Dr. Darwin in England, and Geoffroy Saint-Hilaire (as we shall immediately see) in France, came to the same conclusion on the origin of species in the years 1794–95."[1]

Besides Goethe, three other great German thinkers, Kant, Treviranus, and Oken, set forth,

[1] Origin of Species, Historical Sketch, p. xiv.

between 1790, and 1809, arguments in favor of organic evolution. Of all the authors just mentioned, however, only Saint-Hilaire was a professional naturalist, and even he failed to conceive of the development theory in any thing at all closely like its present form. Dr. Darwin, however, came nearer to a comprehension of the real meaning of organic evolution than any of his contemporaries, and he fully deserves the high praise that has been given him by Ernest Krause: —

> "It is only now, after the lapse of a hundred years, that, by the labors of one of his descendants, we are in a position to estimate at its true value the wonderful perceptivity, amounting almost to divination, that he displayed in the domain of biology. . . . The elder Darwin was a Lamarckian, or, more properly, Jean Lamarck was a Darwinian of the older school, for he has only carried out further the ideas of Erasmus Darwin, although with great acumen; and it is to Darwin, therefore, that the credit is due of having first established a complete system of the theory of evolution."[1]

The justice of this estimate any one may easily verify by reading for himself the thirty-ninth section of Dr. Darwin's most valuable work, the "Zoonomia," published in 1794. In this sec-

[1] The Life of Erasmus Darwin, American edition, pp. 132, 133.

tion he gives a careful summary of his reasons for maintaining the doctrine of organic evolution; but I can only quote here the paragraph in which are summed up his conclusions in regard to the origin of the warm-blooded animals: —

"From thus meditating on the great similarity of the structure of the warm-blooded animals, and at the same time of the great changes they undergo both before and after their nativity, and by considering in how minute a proportion of time many of the changes of animals above described have been produced, would it be too bold to imagine that in the great length of time since the earth began to exist, perhaps millions of ages before the commencement of the history of mankind, — would it be too bold to imagine that all warm-blooded animals have arisen from one living filament,[1] which *the great First Cause* endued with animality, with the power of acquiring new parts attended with new propensities, directed by irritations, sensations, volitions, and associations, and thus possessing the faculty of continuing to improve by its own inherent activity, and of delivering down those improvements by generation to its posterity, world without end?"[2]

It is impossible in a single selection, of whatever length, to give a just idea of the thorough-

[1] Dr. Darwin's use of the word "filament" arises from a misapprehension which he shared, with the naturalists of his time, in regard to the origin of the embryo in the process of generation. The ovum was known to exist, but its importance was not recognized.

[2] Zoonomia, xxxix. 4, 8.

ness with which Dr. Darwin had conceived the principle of development, or of the astonishing quickness of perception with which he laid hold of facts in support of his view. It is simply marvellous that a man so immersed as he was in the cares of a most extensive and laborious medical practice could have mustered together from his own reading and observation such an array of proofs. No doubt something of his scientific and literary productiveness is due to the fact that Dr. Darwin, while riding in the practice of of his profession, "read and wrote much in his carriage, which was fitted up for the purpose."

As is natural enough, we find, on coming from Dr. Darwin to Lamarck, a great advance in exact comprehension and statement of the doctrine of descent. In his "Zoölogical Philosophy," published from 1815 to 1822, occurs the following passage:—

"The systematic divisions of classes, orders, families genera, and species, as well as their designations, are the arbitrary and artificial productions of man. The kinds or species of organisms are of unequal age, developed one after the other, and show only a relative and temporary persistence: species arise out of varieties. The differences in the conditions of life have a modifying influence on the organization, the general form, and the parts of animals, and so has the use or disuse of organs. In the first beginning, only the very simplest and lowest animals

and plants came into existence; those of a more complex organization, only at a later period. The course of the earth's development and that of its organic inhabitants was continuous, not interrupted by violent revolutions." [1]

Of these opinions Haeckel says, —

"These are indeed astonishingly bold, grand, and far-reaching views, and were expressed by Lamarck sixty years ago; in fact, at a time when their establishment by a mass of facts was not nearly as possible as it is in our day."

For just this reason, the impossibility of arraying enough facts in defence of Lamarck's position, his labors remained for almost half a century comparatively unregarded. But during all this time naturalists were again and again recurring to the question of the origin of species; so that, from the year 1790 till 1858, there was hardly a period of five years in which the doctrine of descent was not stated in some form by somebody. In all, more than thirty naturalists and philosophers had by the year 1858 enunciated principles which tended more or less strongly to confirm the truth of the development theory.[2] But it was not till July 1, 1858,

[1] Quoted by Haeckel, Natural History of Creation, i. pp. 112, 113.

[2] Historical sketch preceding Darwin's Origin of Species, also Haeckel's Natural History of Creation, chaps. iv., v.

that the theory was put before the world in a form so authoritative as to compel a hearing, if not an unqualified acceptance, for it, from every man of science. For on this date two papers were read before the Linnæan Society of London, which were to work a revolution in the current modes of thought, not only among zoölogists and botanists, but also among students of many widely separated branches of human knowledge. One of these papers had been forwarded from the East Indies by Alfred Russell Wallace, and contained the result of his observations "On the Tendency of Varieties to depart indefinitely from the Original Type." The other paper, on "The Origin of Species," by Charles Darwin, was the result of over twenty years of study. Speaking of some of his observations while engaged as a naturalist on a trip round the world, and of the light which these observations seemed likely to throw on the origin of species, Mr. Darwin himself says, —

"On my return home it occurred to me, in 1837, that something might perhaps be made out on this question by patiently accumulating and reflecting on all sorts of facts which could possibly have any bearing on it. After five years' work, I allowed myself to speculate on the subject, and drew up some short notes: these I enlarged in 1844 into a sketch of the conclusions which then seemed

to me probable. From that period to the present day [1859] I have steadily pursued the same object."[1]

And the last sentence above quoted was as true at the time of the great naturalist's death, in 1882, as at the date when it was written.

How great Darwin's work was, can nowhere better be learned than in Mr. Wallace's article, "The Debt of Science to Darwin."[2] No one can read this unselfish tribute to Darwin's greatness without forming a high opinion of Wallace as well; for it must be remembered that the latter was an independent discoverer of the origin of species by means of natural selection.

Briefly stated, the reason why Darwin, by general consent, is ranked as one of the foremost scientific men of all time is, that he united, to a degree never surpassed, the genius for making observations and that for reasoning from the results of observation. By possessing both of these rare endowments in the highest degree, Darwin was enabled to do what all other naturalists had failed to accomplish; that is, not only to state that species are descended from other species, but also *to prove the truth of the statement, and to show how the process of specific*

[1] Introduction to The Origin of Species.
[2] Century Magazine, January, 1883.

change was brought about, and new species perpetuated.

Dr. Darwin and Lamarck, indeed, brought forward, in support of the theory of descent, such facts as were known in the latter part of the last and the beginning of the present century; but the best explanation of the derivation of new species that they could give was the supposition that the habits and the wishes of any animal finally brought about such adaptations in its body as were demanded by the conditions of its life. The giraffe, for example, owed its long neck to the fact that its ancestors had for many generations wished and endeavored to reach branches of trees high above the ground, and so gradually the required increase in length of neck was developed.

Of any such powerful agency as natural selection operating to preserve advantageous variations, neither Dr. Darwin nor Lamarck had any conception at all equal to that of Charles Darwin.[1]

---

[1] Dr. Darwin, however, well understood the principle of sexual selection: after a number of other examples of the same general tenor, he says,—

"The birds which do not carry food to their young, and do not therefore marry, are armed with spurs, for the purpose of fighting for the exclusive possession of the females, as cocks and quails.

On the other hand, a distinguished American scientist, Dr. W. C. Wells, in 1813 succeeded in arriving at the principle of natural selection; but he failed to draw any conclusions from it, except in regard to human beings. From this, and from the fact that his theory was not supported by any considerable number of observations, it was productive of even less influence on the thought of the scientific world than Lamarck's theory had been.

In Charles Darwin's hands, however, the doctrine did not fail to be applied, not merely to

---

"It is certain that these weapons are not provided for their defence against other adversaries, because the females in these species are without this armor. The final cause of this contest amongst the males seems to be, that the strongest and most active animal should propagate the species, which should thence become improved."

Also (as has been suggested to me by Professor G. M. Harmon of Tufts College), Dr. Darwin seems to have appreciated the fact of a struggle for existence, and to have recognized the *result* of the process of survival of the fittest, even though he did not quite understand how it was brought about. He says, —

"On the other hand, swiftness of wing has been acquired by hawks and swallows to pursue their prey; and a proboscis of admirable structure has been acquired by the bee, the moth, and the humming-bird, for the purpose of plundering the nectaries of flowers. All which seem to have been formed by the original living filament, excited into action by the necessities of the creatures which possess them, and *on which their existence depends.*"

The Italics are my own.

all animals, but to all plants as well. And, wherever facts to verify the theory in any particular were lacking, Darwin set himself to work to obtain them, from books, by conversation with breeders of animals and with gardeners, or by long series of patient experiments. No one can read the "Origin of Species," or that vast storehouse of information, "Animals and Plants under Domestication," without being greatly impressed by the way in which Darwin made the observations of all men tributary to his own great work. No back number of a horticultural magazine or a poultry-breeder's journal seems to have escaped his attention, while (among more strictly scientific sources of information) he studies the Malay Archipelago through Wallace's eyes, and New Zealand and Australia through those of Dr. Hooker. The great Amazon basin becomes familiar to him through the descriptions of Bates and others, while Central America is known through the studies of Mr. Belt; and so on with a long list of other regions.

From the keepers of the English and foreign zoölogical and botanic gardens a great fund of information was obtained. Nor should it be forgotten that Mr. Darwin's personal acquaintance with the life of some of the most interest-

ing regions of the globe (gathered during his voyage round the world from 1831 to 1836) was extensive and profound.

To this immense fund of knowledge must be added that which he gained by his own careful experiments. His residence, Down House, and the surrounding grounds, during the whole period of his occupancy, constituted an extensive set of apparatus for botanical and zoölogical experiments.

Greenhouses, beehives, dovecotes, poultry-yards, fields, and pastures, all were devoted to the one great work of accumulating *facts* about animals and plants. A single example from among the many that might be cited will show the patient persistency with which Mr. Darwin carried out any line of study: one field was left untouched for thirty years, during which time he was carrying on an elaborate investigation into the habits of the earth-worm.

It is not strange that such ability as Darwin's, so consecrated to the pursuit of science, should have been so fertile in results as to lead Wallace to say of him, —

> "However much our knowledge of nature may advance in the future, it will certainly be by following in the pathways he has made clear for us; and for long years to come the name of Darwin will stand for the typical example of what the student of nature ought to be."

And yet the development theory to-day is not, strictly speaking, "Darwinism," as it is so often called. Very many prominent evolutionists now feel it to be certain that various natural causes bring about much more rapid advances or changes in species than seem to have been recognized by Mr. Darwin. For some such sudden advances as that of the brine-shrimps so often mentioned, and for some phenomena not explained by natural selection, explanations have been offered by Cope and Hyatt, among American writers on the subject, and by Murphy, Mivart, and others in Great Britain.

Mivart even goes so far as almost to repudiate the theory of natural selection, substituting for it an evolution theory of his own. With the immense majority of naturalists, however, natural selection holds the first place among the causes which have given rise to species. The doctrine of descent, in some form, has gained over to its support a vast majority of the English-speaking naturalists of the world. In France it has made little progress,—a fact which may be due to the powerful influence there of Cuvier and Agassiz, two most uncompromising opponents, each in his day, of all theories of organic evolution. In Germany, on the other hand, the theory has met with a most enthusi-

astic reception. A few naturalists, it is true, have remained unconvinced; but such authorities as Adolph Schmidt, Fritz Müller, and, above all, Haeckel, have carried out Darwin's line of argument with great success. To Haeckel, indeed, the name of "the German Darwin" has often, though incorrectly, been applied.

In his fondness for controversy, as well as in the enthusiastic and speculative manner in which the great German zoölogist has applied the principles of evolution to the construction of one vast genealogical tree for the animal, and of another for the vegetable kingdom, he is as little like Darwin as one well could be. But by his profound and far-reaching knowledge of the animal kingdom, his brilliant, fearless style of expression, and his unsurpassed power of popularizing scientific results, Haeckel has done a great work in the cause of his favorite theory. Then, too, by his exhaustive researches concerning the structure and life-history of the sponges, he has done more than any other man utterly to break down the old idea of species. He has indeeed (as already shown[1]) demonstrated, that among chalk-sponges, at any rate, there are no species.

---

[1] P. 22.

In conclusion, a few words must be said about the general agreement of the development theory with the facts of nature, and of the value of the theory as an aid to the comprehension of nature. Tried by a jury of experts, the biologists of Europe and America, the verdict of to-day is overwhelmingly strong for evolution.

Here and there an obstinate juror has stood out; but the general voice of the scientific world is unmistakable. Oscar Schmidt says, —

"Perhaps ninety-nine per cent of all living, or rather, of all working, zoölogists, are convinced by inductive methods of the truth of the doctrine of descent."[1]

Opinions are and may long remain divided as to the share which natural selection has borne in the production of new species; but there is a general agreement as to the certainty that all living organisms, animal and vegetable, have been derived from some few original, simple forms, possibly from one. This agreement is most creditable to the fair-mindedness of the elder generation of naturalists, so many of whom (beginning with Lyell) have laid aside the views of a lifetime to adopt the theory. This result may in no small degree be attributable to the

---

[1] Quoted in Haeckel's Freedom of Science and Teaching, p. 86.

fact that *there is no other theory but that of evolution which brings forward any evidence to show that it naturally accounts for the origin of the species of animals and plants.* All the objections raised against the development theory have been negative, and not positive. The so-called special-creation theory is not, and never was, an answer to the fundamental question, "How are species formed?"

Let one attempt to imagine the *creation* of any new species of animal or plant, not in a remote geological age or a distant country, but in the nearest garden, field, or woods, and he can hardly fail to realize how unmeaningly the words "special creation" are employed. In fact, the whole special-creation idea is itself a fossil, the reminder of a time when no one knew that the earth had any past life-history.

It is impossible, on any save some evolutionary theory, — unless, indeed, one go back and adopt the Oriental belief in a supreme evil spirit governing the world, — to account for the essential selfishness of the world of living beings. Says Mr. Romanes, —

"Amid all the millions of mechanisms and instincts in the animal kingdom, there is no one instance of a mechanism or instinct occurring in one species for the exclusive benefit of another species, although there are a few cases

in which a mechanism or instinct that is of benefit to its possessor has come also to be utilized by other species. Now, on the beneficent design theory, it is impossible to explain why, when all the mechanisms in the same species are invariably correlated for the benefit of the species, there should never be any such correlation between mechanisms in different species, or why the same remark should apply to instincts; for how magnificent a display of divine beneficence would organic nature have afforded if all, or even some, species had been so inter-related as to minister to each other's necessities! Organic species might, then, have been likened to a countless multitude of voices, all singing in one harmonious psalm of praise. But as it is we see no vestige of such co-ordination: every species is for itself, and for itself alone — an outcome of the always and everywhere fiercely raging struggle for life." [1]

Of the light thrown by the development theory on some heretofore obscure facts of the organic world, leading biologists must be the most competent judges. Out of the volumes of evidence to show how points long unintelligible have been cleared up by the theory, I can only quote here and there a line. The whole subject of embryology was utterly mysterious before the evolution idea was brought forward to give reasons for some of the curious facts which have been outlined in a previous chapter. Pro-

[1] Scientific Evidences of Organic Evolution, pp. 74, 75.

fessor Allen Thomson was led to say in his address as president of the British Association in 1877, —

"I consider it impossible, therefore, for any one to be a faithful student of embryology, in the present state of science, without at the same time becoming an evolutionist."

Professor Huxley's opinion in regard to the bearings of the facts of paleontology on evolution has already been quoted. Professor H. A. Nicholson, a very high authority, and a very cautious reasoner, says, —

"Upon the whole, it must be unhesitatingly replied, that the evidence of paleontology is in favor of the view that the succession of life-forms on the globe has been to a large extent regulated by some orderly and constantly acting law of modification and evolution. Upon no other theory can we comprehend how the fauna of any given formation is more closely related to that of the formation next below in the series and to that of the formation next above than to that of any other series of deposits. . . . On no other view can we explain the appearance of 'intermediate' or 'transitional' forms of life filling in the gaps between groups now widely distinct."[1]

To the evidence of zoölogy and botany there is no need of here adding any thing further

[1] Ancient Life-History of the Earth, pp. 372, 373.

than has already been cited in earlier chapters. Such works as Darwin's "Animals and Plants under Domestication" and Wallace's "Malay Archipelago" are crammed from cover to cover with the amplest testimony. In short, as Romanes has well put it, we do not need any more testimony: nothing but a *demonstration*, such as is possible in the mathematical, but impossible in the natural-history, sciences, could make the fact of organic evolution more certain than it now is. But objectors have said, the picture of a world in which the very existence of each individual depends on its power to crowd other individuals out of existence is not a pleasant one. What of that? Science is concerned only to learn and to state the facts of the universe, not to sugar-coat them into palatableness. And the man, be he scientist or not, who chooses to disbelieve a theory because it does not fall into line with his personal preferences, is even less logical than the Hindoo, who bought and destroyed the microscope that had shown him the impossibility of so much as taking a drink of water without violating his religion by destroying animal life.

The value of the development theory to the biological sciences is twofold: it has rendered unnecessary the childish supposition that each

new animal or plant must have been conjured into existence by an invisible and unintelligible Power, and it has correlated the whole series of forms of life into a comprehensible record of progress. Species, living and dead, that were but the toys with which naturalists have been playing since Aristotle's day, have for us suddenly become the legions, which, on forgotten continents, and beneath oceans whose beds now form the mountain tops of earth, have fought out the great battle of life.

APPENDICES.

APPENDIX A.

By the animal kingdom is meant the whole series of living and extinct species of animals. It has been variously divided into groups. One of the most comprehensible as well as natural classifications gives eight sub-kingdoms, as follows:[1] —

1. *Protozoa*, the animalcule sub-kingdom — animals which have neither a general body-cavity, nor a nervous system, and are single-celled.

2. *Polystomata*, the sponge sub-kingdom — animals which have an internal cavity with a three-layered wall, one outlet, and usually many inlets, with no parts or organs set aside for special purposes, but consisting of many cells.

3. *Cœlenterata*, the jelly-fish sub-kingdom — animals with a stomach-cavity, and a body-cavity extending out from this. The parts of the body are arranged regularly around a centre as the spokes of

[1] The language a little simplified from Macalister's Zoölogy: Invertebrata, p. 14.

a wheel are around the hub; that is, they have a radiate symmetry.

4. *Echinodermata*, the star-fish sub-kingdom — animals with a body-cavity separate from the stomach, a nervous system, and a system of water-tubes, which aid the animal in locomotion: the symmetry more or less completely radiate.

5. *Vermes*, the worm sub-kingdom — animals which consist of two halves, or have bilateral symmetry, are composed of a series of joints or segments, have no jointed limbs, and have a water-tube system, which does not aid in locomotion.

6. *Mollusca*, the shell-fish sub-kingdom — animals which have soft bodies covered by a leathery portion called the "mantle," no jointed limbs, a heart and blood-vessels (or something resembling them), forming a circulatory system, often a shell outside the body, and frequently an unsymmetrical nervous system; that is, one in which there are not two equal or nearly equal sides to each part.

7. *Arthropoda*, the crab, spider, and insect sub-kingdom — animals which have bodies made up of a series of joints, a symmetrical nervous system, a skeleton outside of the body, and jointed limbs.

8. *Vertebrates*, the back-boned sub-kingdom — animals which have a skeleton within the body, a brain, and a back-bone.

The most important of the sub-kingdoms is further divided as follows: —

Vertebrata.
- Fishes.
- Amphibians (toads, frogs, newts, etc.).
- Reptiles (snakes, lizards, etc.).
- Birds.
- Mammals, or warm-blooded quadrupeds.

As an example of the way in which a class is subdivided into smaller groups, the mammalia may be taken. This class consists of sixteen orders, as follows: —

(1) Monotremes (Australian duck-mole, etc.).
(2) Marsupials (kangaroo, opossum, etc.).
(3) Edentates (ant-eater and armadillo).
(4) Sloths.
(5) Sirens (dugong, manatee, etc.).
(6) Ungulates (horse, rhinoceros, hog, deer).
(7) Cetacea (whales, etc.).
(8) Pinnipeds (seals and walruses).
(9) Carnivores (cat, dog, weasel, and bear).
(10) Hyracoids (conies).
(11) Rodents (rats, mice, squirrels, etc.).
(12) Proboscides (elephants).
(12) Lemurs (aye-aye, etc.).
(14) Insectivores (shrews, moles, hedgehogs).
(15) Cheiropters (bats).
(16) Primates (monkeys, apes, and man).

The subdivisions of the vegetable kingdom, according to one of the simplest plans of classification, are as follows: —

SERIES I. — *Flowering Plants.*	Growth of stem on outside only. Young plantlet, with two or more seed-leaves.	CLASS I. Exogens, or Dicotyledons.	SUB-CLASS I. Angiosperms.	Seeds in a seed-vessel (most garden vegetables, the hard-wood trees, etc.).
			SUB-CLASS II. Gymnosperms.	Seeds not in a seed-vessel (the evergreen, cone-bearing trees).
	Growth of stem on inside. Young plant with only one seed-leaf.	CLASS II. Endogens, or Monocotyledons.		Palms, lilies, grasses, rushes, etc.
SERIES II. — *Flowerless Plants.*	A stem and foliage containing	Woody material.	CLASS III. Acrogens.	Ferns, "ground-pines," etc.
		No woody material.	CLASS IV. Anophytes.	Mosses, liverworts, etc.
	No distinction of stem and foliage, but all blended in one mass; often microscopic, sometimes consisting of but a single cell.		CLASS V. Thallogens.	Moulds, "toad-stools," seaweeds, "frog-spit," etc.

APPENDIX B.

In the vegetable kingdom a parallelism may be traced between the development of the individual and the evolution of the type, somewhat similar to that observed in the animal.

The lowest plants, like the lowest animals, are unicellular, or at most colonies of a few similar cells. The first step in advance consists in the aggregation of these into definite groups, — the plant-body, some of whose members serve one office, some another. Among the lowest plants with such a body are the filamentous algæ. Other species, little higher in the scale, have their cells arranged in flat, often more or less branched fronds. A spore from either of these reproduces the form which bore it, and which persists through the life of the plant.

In many of the liverworts, which stand higher in the series, a spore in germinating produces a thalloid plant, which, after vegetating for a considerable time, bears sexual organs. By their mutual action these give rise to a body smaller than the first, which lives but a short time, and in which the spores (reproductive bodies calculated for dissemination) are formed. This body, the sporogonium, though it

maintains its connection with the parent plant, is in reality a distinct organism. In the life-history of the liverworts there are, therefore, two well-marked phases, one of which invariably takes its origin from the other: in other words, these plants possess an alternation of generations, a thalloid sexual form alternating with a non-sexual form of even a slighter degree of organization.

The spore of a mass in germination produces a confervoid organism very similar at first to the filamentous algæ, but which, in its active vegetative life, ultimately buds into a plant-body having stem and leaves, as in the higher plants. This is the sexual generation of the mass; and from the union of its reproductive cells a sporogonium results, which lives but a short time, and ends by bearing the non-sexual spores.

In each of these groups of plants the sexual generation is the most highly developed, and is the most conspicuous, part of the plant; the non-sexual sporogonium being apparently an outgrowth from it. In the more highly organized vascular cryptogams there is a similar alternation of generations; but the non-sexual plant (bearing the spores) very much exceeds the sexual plant, which is commonly thalloid and of slight development, never reaching the proportions of the larger liverworts, and in some of the groups being developed only sufficiently to bear the reproductive organs.

Two examples may illustrate this. In the ferns

the spore gives rise to a small prothallus, very similar to the thalloid liverwort, but seldom exceeding a quarter of an inch in any of its dimensions, and living but a short time before its vegetation is cut short by the early development of sexual organs, from the interaction of which there results a perennial plant, the fern, which in some tropical species reaches the proportions of a tree. This, the non-sexual generation, again bears spores, which in germinating develop prothalli.

In the second group of vascular cryptogams chosen for illustration (the rhizocarpeæ), there are two sorts of spores, — large ones, the macrospores, and small ones, the microspores. In germination they produce microscopic prothalli, which in some species result merely from the segmentation of the spores, with scarcely any increase in their size; so that the sexual generation is barely large enough to burst the wall of the spore, after doing which its career is soon terminated by the precocious development of reproductive organs. The prothalli from macrospores are uniformly female: those from microspores are constantly male. On the other hand, the non-sexual generation which results from the process of fertilization is of considerable size and of complex structure.

The flowering plants, to which an observer's attention is most frequently turned, show the same alternation of generations, but attended by a still greater precocity, and consequently an inferior devel-

opment, of the sexual generation. As a result of the different mode of fertilization in these plants, the macrospore remains attached to the tissues in which it is produced, not only until the process of fertilization has been accomplished, but even until the resulting non-sexual plant has passed through the earlier stages of its embryonic development.

Pines and other gymnosperms afford a connecting link between the higher cryptogams and the more highly specialized flowering plants. In their flowers the macro- and micro-spores are represented respectively by a large cell of the ovule (the embryo sac) and the pollen grain. Each of these produces a cellular prothallus in what may be called its germination ; but the sexual plants (the endosperm and pollen tube) never assume large proportions. Even in some species in which the macrospore and its prothallus are larger than in ferns, the latter is not noticed as a distinct plant, because of its concealment in the ovule.

The great mass of flowering plants (monocotyledons and dicotyledons) show even a slighter development of the female prothallus, which consists of only a few naked cells (embryo vesicle, antipodal cells, etc.) enclosed in the embryo sac, or macrospore, and a similar incompleteness in the male prothallus, which is reduced to a few nuclei in the pollen grain (microspore), or its tube.

From this brief account, it will be seen that the simple permanent condition of the algæ and fungi

persists in all of the higher plants as a more and more fugitive stage in their existence; its arrested development being correlated with the increasing precocity in the performance of the sexual function with which it is charged. In the mosses and liverworts it is still most important; but in the vascular cryptogams it successively descends from a structure of small size, but still self-supporting, to one of no significance, except for its reproductive office, which it executes at the expense of food stored in it by the correspondingly important non-sexual generation. Finally, in the flowering plants, even its individual existence is apparently merged in that of the alternating stage, a part of which, the flower, has even appropriated its title of the sexual organ, so completely is its nature as a separate plant concealed.

INDEX.